Gondwana Research xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Gondwana Research

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

Geochemistry and geochronology of the Delinggou Intrusion: Implications for the subduction of the Paleo-Asian Ocean beneath the North China Craton

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ARTICLE INFO

Article history:
Received 4 September 2015
Received in revised form 30 November 2015
Accepted 26 January 2016
Available online xxxx

Keywords:
Central Asian Orogenic Belt
Continental margin arc
Diorite
Paleo-Asian Ocean
Subduction
North China Craton

ABSTRACT

The formation and evolution of the Central Asian Orogenic Belt (CAOB) are intimately related to the opening and closure of the Paleo-Asian Ocean. The final closure led to amalgamation or collision between the CAOB and North China Craton. However, the issue about the subduction polarity and final closure of the Paleo-Asian Ocean has long been debated. In order to resolve this issue, we carried out a detailed geochemical and age study on the Delinggou Intrusion from the Siziwangqi area of central Inner Mongolia, at the northern margin of the North China Craton. The Delinggou Intrusion consists predominantly of diorite and quartz diorite, with minor gabbroic diorite. U–Pb zircon dating indicates that the intrusion was emplaced during early Carboniferous (330 to 343 Ma). Geochemically, the rocks are metaluminous and belong to the calc-alkaline series. They are enriched in large ion lithophile elements (LILE, e.g., Rb, Sr and Ba), and depleted in high field strength elements (HFSE, e.g., Zr, Nb, Hf, Ta and Ti). The Delinggou rocks were probably generated by partial melting of an enriched subcontinental lithospheric mantle, further contaminated by crustal material during the magmatic differentiation in a continental arc setting. We conclude that the Paleo-Asian Ocean underwent southward subduction beneath the North China Craton, and the subduction initiated in the Carboniferous (343–330 Ma), but the final ocean closure time is not yet constrained.

1. Introduction

The Paleo-Asian Ocean was a long-lived ocean separating the East European and Siberia Cratons in the north and the Tarim and North China Cratons in the south (Fig. 1), and its opening resulted from the breakup of the Rodinia supercontinent and its expansion and final closure led to the development of the Central Asian Orogenic Belt (CAOB), which is considered as the largest accretionary orogen in the Earth's history (Sengör et al., 1993; Jahn et al., 2000a, 2000b, 2001; Wu et al., 2000; Badarch et al., 2002; Dobretsov et al., 2003; Xiao et al., 2003, 2004, 2009a, 2009b; Jahn, 2004; Li, 2006; Charvet et al., 2007; Windley et al., 2007; Kröner et al., 2008; Wilhem et al., 2012). Accordingly, it attracts geologists from different countries to carry out extensive field-based structural, petrological, geochemical, geochronological and geophysical investigations on this orogen for more than two decades. These investigations have produced a large number of new data and competing models (Kröner et al., 2008, 2011, 2014; Geng et al., 2009, 2011; Cai et al., 2010, 2011a, 2011b, 2012a,b; Cai et al., 2014a, 2014b; Jiang et al., 2010, 2012, 2015; Yuan et al., 2010, 2011; Xiao et al., 2013, 2015a, 2015b; Xiao and Santosh, 2014; Chen et al., 2014; Han et al., 2015). However, most of these investigations have focused on geological processes related to the northward subduction of the Paleo-Asian Ocean beneath the southern margins of East Europe–Siberian and microcontinental blocks or island arcs and oceanic islands within the Paleo-Asian Ocean (Jahn et al., 2000a, 2000b; Wu et al., 2000, 2007; Buchan et al., 2002; Dobretsov et al., 2003; Xiao et al., 2003, 2004, 2009a, 2009b; Safonova et al., 2004, 2008; Helo et al., 2006; Windley et al., 2007; Kröner et al., 2008; Sun et al., 2008; Utsunomiya et al., 2009; Wang et al., 2009; Lehmann et al., 2010; Schulmann and Paterson, 2011; Wilhem et al., 2012). Comparatively, however, less work has been done on geological processes on the northern margins of Tarim–North China. Thus there are many controversies on issues of what geological processes and events had happened along the northern margin of Tarim–North China before the final closure of the Paleo-Asian Ocean. At the center of these controversies is whether or not the Paleo-Asian Ocean underwent southward subduction beneath the northern margins of the North China Craton during Paleozoic time, and if such southward subduction did exist, when did it

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http://dx.doi.org/10.1016/j.gr.2016.01.007
1342-937X/

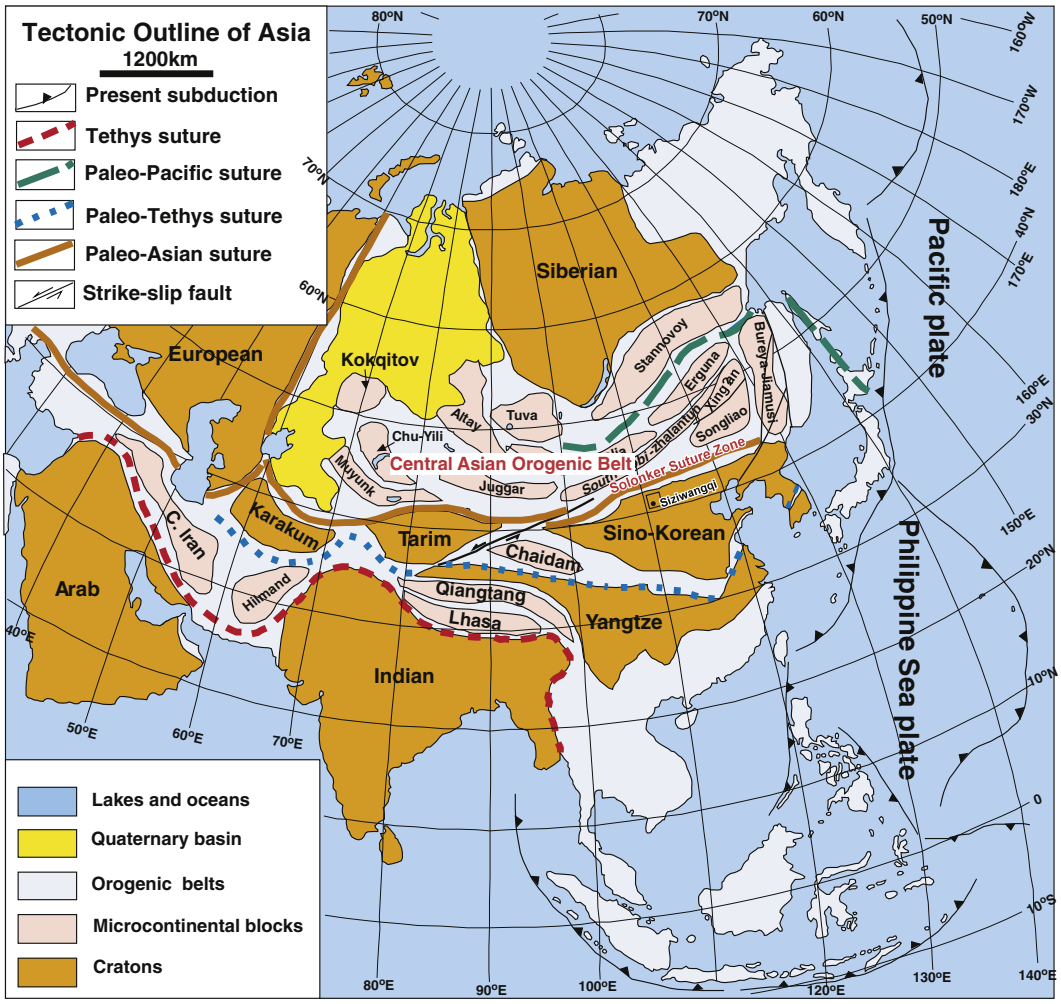

Fig. 1. Tectonic map showing the major tectonic units in East Asia. A square indicates the study area. Modified after Li (2006).

commence and how long it lasted? Such debates are reflected by distinct and largely mutually exclusive models that have been proposed for the eastern segment of the Paleo-Asian Ocean, whose closure led to amalgamation of the North China and Siberia Cratons along the Solonker Suture Zone (Fig. 1).

For example, controversy has long surrounded the polarity of subduction of the eastern sector of the Paleo-Asian Ocean, with one school of thought believing that the subduction was northward beneath the Siberian Craton (Hsu et al., 1991; Sengör et al., 1993), whereas others argue for a double-sided subduction model with one side subducted beneath the northern margin of The North China Craton and the other side beneath the Siberian Craton (Tang, 1990; Wang et al., 1991; Gao et al., 2001; Xiao et al., 2003; Windley et al., 2007; Jian et al., 2008; Xu et al., 2013; Eizenhöfer et al., 2014, 2015a, 2015b; Xiao and Santosh, 2014; Zhang et al., 2014a, 2014b, 2015a, b). For those researchers who favor such double-sided subduction models, it also remains controversial regarding the timing of the commencement of the southward subduction beneath the North China Craton, with some researchers arguing that the southward subduction had been initialized since the Early Paleozoic (Jian et al., 2008; Xu et al., 2013), whereas others suggest that the Paleo-Asian Ocean was subducted beneath the northern margin of the North China Craton during both Early and Late Paleozoic times (Wang et al., 1991; Gao et al., 2001; Xiao et al., 2003; Windley et al., 2007). Most recently, Zhang et al. (2014a) proposed that the southward subduction had not started until the Late Paleozoic, whereas the northern margin of the North China Craton represented a passive continental margin during Early Paleozoic time, and then changed into an Andes-type active continental margin following the initialization of the southward subduction of the Paleo-Asian Ocean.

Thus it can be seen that so far there is no consensus on the tectonic setting of the northern margin of the North China Craton during Paleozoic time. This forms the justification for this research work in which we carried out detailed field-based petrological, geochemical and geochronological investigations on the Paleozoic Delinggou Intrusion in the Siziwangqi area of central Inner Mongolia. Sited on the northern margin of North China, the Sizhwangqi area is one of the most potential areas for resolving the above controversial issues because it is located just south of the Solonker Suture Zone (Fig. 1), which is considered as the final site where the North China Craton collided with the Siberian Craton in association with the final closure of the Paleo-Asian Ocean to form the eastern segment of the CAOB (Sengör et al., 1993; Chen et al., 2001). We aim to answer questions of whether or not the Paleo-Asian Ocean had experienced southward subduction beneath the northern margin of the North China Craton before its closure and when the southward subduction initially started, if such subduction did exist. The results enable us to determine the precise ages and tectonic settings of Paleozoic igneous rocks at the northern margin of the North China Craton, and provide important insights into an understanding of formation and evolution of the Central Asian Orogenic Belt.

Please cite this article as: Chen, N.H.-C., et al., Geochemistry and geochronology of the Delinggou Intrusion: Implications for the subduction of the Paleo-Asian Ocean beneath the No..., Gondwana Research (2016), http://dx.doi.org/10.1016/j.gr.2016.01.007