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Linking the Alxa Terrane to the eastern Gondwana during the Early Paleozoic: Constraints from detrital zircon U–Pb ages and Cambrian sedimentary records

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ABSTRACT

The detrital zircon ages of the Early Paleozoic Xiangshan Group in the southeastern Alxa Terrane show that the lower age limit for the Xiangshan group is 512 Ma. The Xiangshan Group is older than the Middle Ordovician strata in the study region and is the Middle–Late Cambrian in age, which is the same age as the fossils found in it. The detrital zircon ages record the Grenville and Pan-African Orogenic Events, and the major age peaks are 963 Ma, 1179 Ma, 551 Ma and 2517 Ma. The North China Terrane, the Alxa Terrane and the Qilian Orogenic Belt were not the provenances of the Xiangshan Group. The age spectrum of the Xiangshan Group is similar to terranes associated with eastern Gondwana. The sandstone composition modes of the Xiangshan Group indicate that the source areas were the recycled orogenic belts. The zircons in the Xiangshan Group with an age peak at ca. 963 Ma may come from the Eastern Ghats–Rayner orogenic belt or other terranes located to the north of eastern Gondwana. The zircons with a peak at ca. 1179 Ma may come from the Wilkes–Albany–Fraser orogenic belt. Those with a peak at ca. 551 Ma may come from the Prydz–Darling orogenic belt, and the zircons with a peak at ca. 2517 Ma may be from northern India and the Yilgarn Craton in Western Australia. Similar paleontology, paleomagnetic data and detrital zircon age spectra indicate that the Alxa Terrane was located to the east of the South China Terrane and to the north of the eastern Gondwanan continent (present coordinates).

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1. Introduction

In the reconstruction of supercontinents during the Neoproterozoic and Early Paleozoic, the locations of the main tectonic units of East Asia, such as the North China Terrane, the Yangtze Terrane and the Tarim Terrane, are under considerable debate (Huang et al., 1999a,b, 2000a, 2000b, 2001; Metcalfe, 2006; Li et al., 2008; McKenzie et al., 2011a; Cawood et al., 2013; Cocks and Torsvik, 2013; Metcalfe, 2013). One school of thought puts South China (including the Yangtze Terrane and Cathysian Terrane) in the center of the Rodinian Supercontinent (Li et al., 2008 and references therein). Another school however argues that South China was located to the north of Australia and India in eastern Gondwana (Cawood et al., 2013; Xu et al., 2013). Huang et al. (1999a) put the North China Terrane to the east of Antarctica, but Veevers (2000) suggested it belonged to the north part of Australia, and Zhao et al. (1993) argued that the North China Terrane was situated to the northeast of Australia (present coordinates). Some recent studies showed that the age components of the basement of the Alxa Terrane are similar to those of the North China Terrane (J.X. Zhang et al., 2013; Wu et al., in press), but similar age components have also been found in some other cratons (Condie et al., 2009). Moreover, many studies have found that the Alxa Terrane (regarded as the western extension of the North China Terrane) differs from the North China Terrane in basement composition and tectonic evolution but is similar to the Yangtze Terrane (Li et al., 2005; Geng et al., 2010 and references therein; Dan et al., 2012). Li et al. (2012) and Zhang et al. (2011, 2012) argued that the Alxa Terrane collided with the North China Terrane in the Early Paleozoic. J. Zhang et al. (2013) suggested that it occurred at the end of the Early Paleozoic, but Yuan and Yang (in press-a, 2015b) argued that it happened at the end of the Late Paleozoic. Ge et al. (2009) even suggested that the collision between the Alxa Terrane and the North China Terrane finished in the Mesozoic. Therefore, the paleogeographic location and tectonic attributes of the Alxa Terrane during the Early Paleozoic are the key parameters in understanding the relationship between the Yangtze Terrane and the North China Terrane, their locations relative to eastern Gondwana and their respective tectonic evolution.

In the southeastern Alxa Terrane, there is a set of Early Paleozoic deep-water turbidites (the Xiangshan Group), whose age and provenances are unknown or in heated debate. Some authors have argued that the sediments are the Middle Cambrian and sourced from the North China Terrane (BGMRNHAR, 1990, 1996; Zhou and Xiao, 2010;

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Zhang et al., 2011), but others have insisted on the Middle Ordovician (Zhang, 1989; Li, 1997; Wang and Zheng, 1998). Additionally, Yuan and Yang (2012) argued that Australia was the main provenance of the Xiangshan Group. Using the method of detrital zircon age dating of the Xiangshan Group, the lower limit age for the deposition of the Xiangshan Group can be fixed, and the provenances of the group can be deduced with the addition of paleocurrent and sandstone composition data. Based on these data, the paleogeographic position of the Alxa Terrane when the Xiangshan Group was deposited will be discussed.

2. Geological setting

2.1. Tectonic location of the Alxa Terrane

The Alxa Terrane is located to the south of the Central Asian Orogenic Belt (Windley et al., 2007; Xiao et al., 2010; Safonova et al., 2011; Yarmolyuk et al., 2012; Feng et al., 2013; Kröner et al., 2014; Zheng et al., 2014). The Ordos Terrane (North China Terrane) lies to the east, separated from the Alxa Terrane by the Mesozoic Helan Shan thrust belt which was caused by the eastward compression of the Alxa Terrane (Liu, 1998; Darby and Ritts, 2002). However, the location of boundary between the Alxa Terrane and the Ordos Terrane is under debate due to the superimposition by the strong eastward thrusting in the Late Jurassic and NW–SE extension during the Cenozoic (Zhang et al., 2011; J. Zhang et al., 2013 and references therein; Molnar and Tapponnier, 1975). Because similar Late Paleozoic marine strata as those in the North China Terrane distribute in the Helan Shan, we just put the boundary along the western Helan Shan and link it with the Bayanwulashan fault to the north (Fig. 1) (J. Zhang et al., 2013). To the west of the Alxa Terrane is the Beishan Orogenic Belt with the Engeerwusu ophiolites as the boundary between them (Wang et al., 1998); recent studies indicated that the Paleo-Asian Ocean closed along the north Alxa Terrane to form the Engeerwusu ophiolites at ca. 275 Ma (Feng et al., 2013; Zheng et al., 2014). There is no consistent view on the southern boundary of the Alxa Terrane; some authors argued that the Longshoushan-Western Ordos fault is the boundary (Zhang et al., 2009 and references therein), however, different geophysical observations showed that the crustal structures of the Hexi Corridor (i.e. Hexizoulang Terrane, Laurie and Burrett, 1992) to the south of the fault are similar to those of the Alxa Terrane to the north (Fig. 2) (Gao et al., 1999; Xiao et al., 2012, submitted for publication), and not only similar metamorphic Early Paleozoic strata but also Late Paleozoic clastic strata with coal beds were all found in both regions (BGMRNHAR, 1990, 1996; Zhang et al., 2011, 2012). Moreover, the Hexizoulang Terrane was looked as the southern passive continental margin of the Alxa Terrane during the Early North Qilian Orogeny (Xiao et al., 2009). Therefore, we put the southern boundary of Alxa Terrane along the North Qilian thrust fault of the present Qinghai–Tibetan Plateau just as Tapponnier et al. (1990) had argued (Fig. 1).

2.2. Tectonic evolution of the Alxa Terrane since the Late Paleozoic

The Alxa Terrane has a long and complicated history, and different models have been proposed (Zhao et al., 2005; Dan et al., 2012; J. Zhang et al., 2013; J.X. Zhang et al., 2013; Yuan and Yang, in press-a, 2015b). In our view, the Alxa Terrane may attach to the North China Terrane during the Devonian (J. Zhang et al., 2013, and our unpublished data). During the Late Paleozoic, the study region underwent extension which may be caused by the northward movement of the Alxa Terrane (Huang et al., 2008). Since the Mesozoic the study region was in the intraplate environment, and strong eastward thrusting occurred in the Late Jurassic (Zhang et al., 2004a,b). The youngest event is the intraplate deformation caused by the India–Eurasia Collision in the Cenozoic (Fig. 2) (Burchfiel et al., 1989, 1991; Zhang and Cunningham, 2010). Due to the above strong tectonic events, the deformation of the Xiangshan Group is very complicated; a series of arcuate thrusts and folds convex to the northeast developed in the Xiangshan Group (Li, 1999; Zhang et al., 2004a), and Type I refolded folds developed widely in it (our unpublished data).

2.3. Outline of the Xiangshan Group

The Xiangshan Group is distributed in the Xiangshan region in the southeastern Alxa Terrane (Figs. 1, 2). The Xiangshan Group is named by Hüs et al. (1998) as the "Qingtongxia Flysch" with a maximum thickness of ca. 8000 m (BGMRNHAR, 1990, 1996). The group is divided into

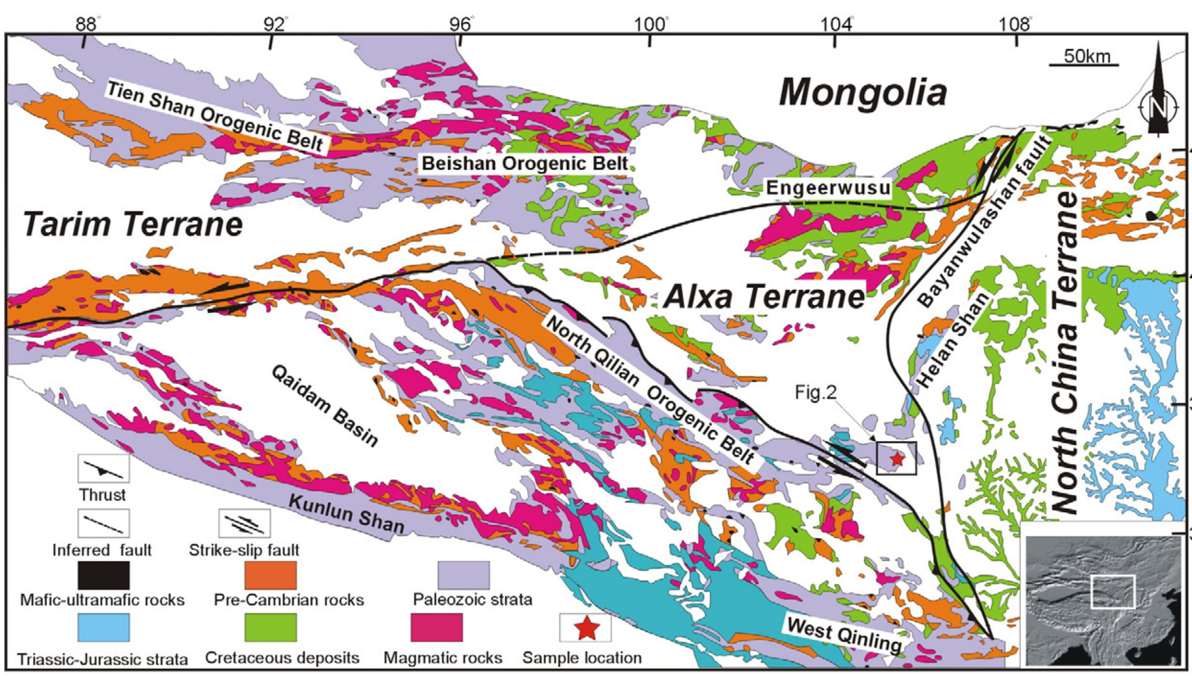

Fig. 1. Geological map of the Alxa Terrane and its vicinity.

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