Journal of Asian Earth Sciences 97 (2015) 197–210

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

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

Geochemistry and U–Pb zircon dating of the Toudaoqiao blueschists in the Great Xing'an Range, northeast China, and tectonic implications

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ARTICLE INFO

Article history:
Received 15 February 2014
Received in revised form 4 July 2014
Accepted 5 July 2014
Available online 24 July 2014

Keywords:
LA-ICPMS U–Pb zircon dating
Toudaoqiao blueschist
High-pressure metamorphism
Early Paleozoic
Central Asian Orogenic Belt

ABSTRACT

The Toudaoqiao Complex is a sequence of high-pressure metamorphic rocks located along the suture zone that separates the Xing'an and Erguna blocks in northeast China. The rocks were metamorphosed up to epidote–blueschist facies at P–T conditions of approximately 0.9–1.1 GPa and 320–450 °C. Lithological associations and major and trace element compositions indicate that the blueschists are metabasalts with ocean island basalt (OIB) and normal mid-ocean ridge basalt (N-MORB) affinities, similar to those of the Philippines intraoceanic accretionary complex formed by subduction of oceanic crust. Magmatic zircons extracted from two samples of the epidote–blueschist facies metabasalts from the North Mountain in the Toudaoqiao Complex exhibit $^{206}Pb/^{238}U$ ages of 511 ± 5 and 516 ± 17 Ma, whereas a greenschist from the South Mountain has a $^{206}Pb/^{238}U$ age of 511 ± 2 Ma; These data show that the protoliths of the Toudaoqiao Complex are of early Paleozoic age. In addition, a granitic dike from the South Mountain exhibits a weighted mean $^{206}Pb/^{238}U$ age of 492 ± 1 Ma. These ages constrain the timing of high-pressure metamorphism in the Toudaoqiao Complex to 490–510 Ma. The new data support the view that the suture zone between the Xing'an and Erguna blocks is the Toudaoqiao–Xinlin Fault, rather than the Derbugan Fault as previously thought. This suture, which extends from Xinlin, through Toudaoqiao, and southern Mongolia, named the 'South Mongolia–Toudaoqiao–Xinlin Suture Zone', may be an important boundary between the Central Mongolia–Erguna and Xing'an blocks.

1. Introduction

Northeast China and adjacent regions are part of the central East Asian continent and include both the Central Asian Orogenic Belt (CAOB) and Late Jurassic to Early Cretaceous circum-Pacific accretionary complexes (Fig. 1). The region developed along the Pacific margin between the Siberia and North China cratons, and has traditionally been subdivided into a series of blocks (microcontinents) separated by terrane-bounding faults. The major units in this area are the Erguna, Xing'an, Songliao, and Jiamusi–Khanka blocks (Fig. 1). The eastern region, including the Jiamusi–Khanka–Bureya Block, the Nadanhada Terrane, and the Sikhote-Alin region of the Russian Far East (Fig. 1), belongs to the Pacific margin (Xu et al., 1987; Faure and Natal'in, 1992; Faure et al., 1995; Maruyama, 1997). The central region comprises the compound Songliao–Zhangguangcai Block and the western region includes the Erguna and Xing'an blocks, which together form part of the CAOB that marks the broad collision zone between the North China and Siberian cratons. This region is dominated by suture zone mélanges, Paleozoic syn-collisional granitoid belts, and Mesozoic post-orogenic A-type granites (Sengör and Natal'in, 1996; Wu et al., 2002). However, the nature of the boundary between the Erguna and Xing'an blocks remains controversial.

The position and timing of the closure of the suture between the Xing'an and Erguna blocks are both still a matter of debate. Some studies have considered that the Derbugan Fault (or Derbugan Metallogenic Belt; Ren et al., 1999a, 1999b; Fig. 2a) is the eastward extension of the South Mongolian suture in eastern Mongolia, which is an important suture zone between the compound Erguna–Central Mongolian and Xing'an blocks (Huang et al., 1977; HBGMR, 1993; Ren et al., 1999a, 1999b; Wu et al., 2003). However, a recent study indicated that the Derbugan Fault is a Mesozoic extensional belt with an age of 115–130 Ma (Zheng et al., 2009) and therefore, it cannot be the suture zone. In contrast, Zhou and Wilde (2013) argued that the suture extends eastwards from the

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http://dx.doi.org/10.1016/j.jseaes.2014.07.011
1367-9120/

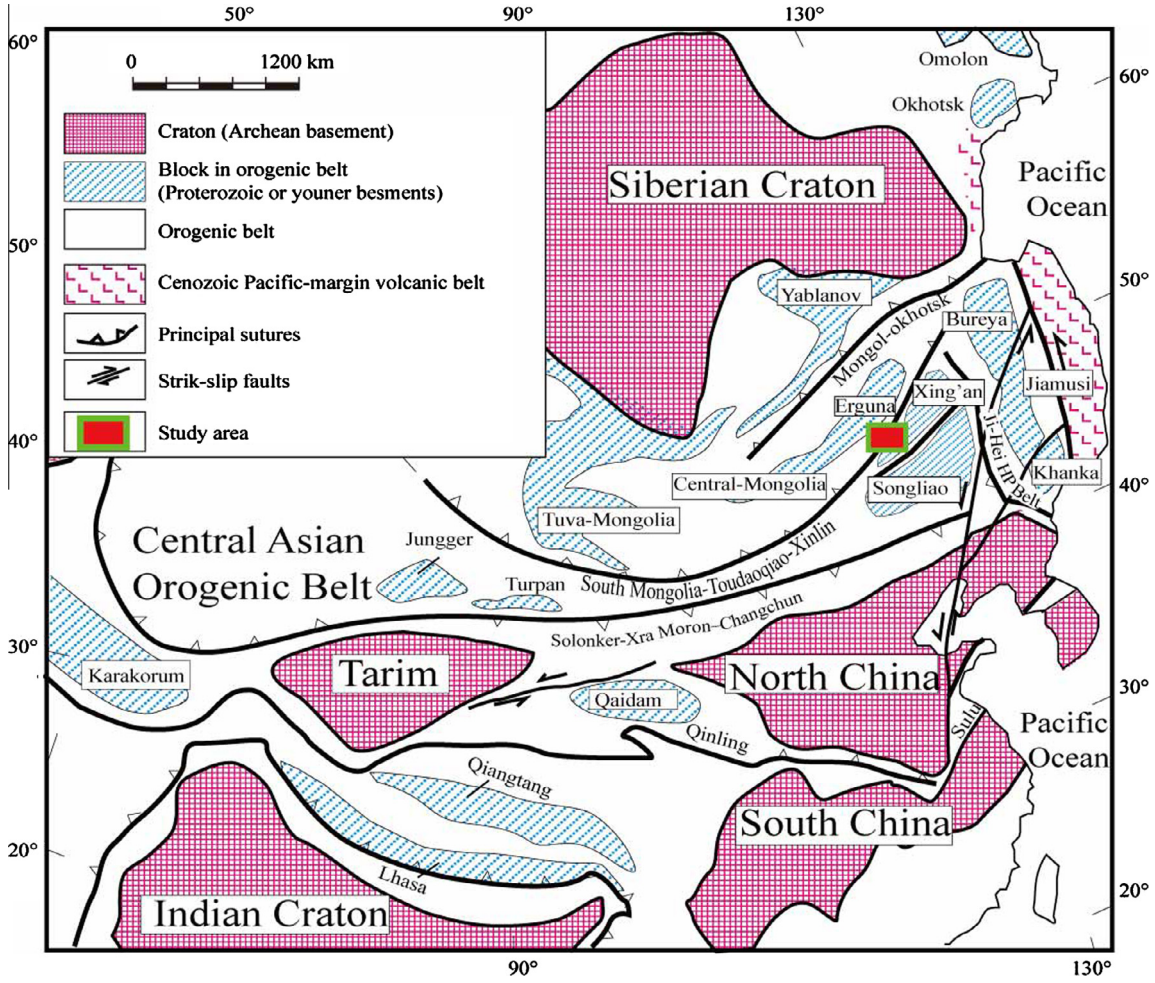

Fig. 1. Schematic tectonic map showing the main subdivisions of central and eastern Asia and location of the study area (modified from Zhou et al., 2009).

South Mongolian suture through the Toudaoqiao and Xinlin areas, and termed the fault the 'South Mongolian–Toudaoqiao–Xinlin Suture Zone' (Figs. 1 and 2a). In this suture, high-pressure blueschists are found at Toudaoqiao, Pan-African granulite-facies rocks are exposed at Xinghuadukou (Zhou et al., 2011a, 2011b), syn-collisional migmatites crop out at Tahe (Ge et al., 2005; Wu et al., 2011), and an ophiolitic complex is found at Xinlin (Li, 1991). However, no high quality geochronological data are currently available for the blueschist facies rocks at Toudaoqiao, which makes it difficult to place the terrane in a reliable tectonic context.

In this paper, we present geochemical and laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) U–Pb zircon data for the blueschist facies metabasalts of the Toudaoqiao Complex. These data enable evaluation of the nature and age of the protolith to the blueschists, and also constrain the timing of metamorphism. Our results provide further insights into the position and timing of the Toudaoqiao–Xinlin high-pressure belt with respect to the Erguna and Xing'an blocks.

2. Geological setting and samples

2.1. Geological setting

The Great Xing'an Range has traditionally been considered to be the eastern part of the Paleozoic CAOB or Altaidas, located between the Siberian and North China cratons (Sengör et al., 1993; Sengör and Natal'in, 1996; Natal'in, 1991; Natal'in and Borukayev, 1991; Ren et al., 1999a, 1999b; Jahn et al., 2000; Jahn, 2004; Xiao et al., 2003, 2004a, 2004b; Li, 2006; Windley et al., 2007; Kröner et al., 2011, 2014). The range consists of a collage of several micro-continental blocks or terranes (Tang, 1990; Wilde et al., 2000, 2003; Li, 2006; Zhou et al., 2009, 2010a, 2010b, 2010c, 2012a; Zhou and Wilde, 2013; Wu et al., 2011; Xu et al., 2013), including the Erguna Block in the northwest and the Xing'an Block in the southeast, separated by the Toudaoqiao–Xinlin or Derbugan faults (Fig. 2a).

The Xing'an Block consists of four main rock series: the Xinghuadukou Complex or 'group'; early Paleozoic gabbro and granitoids; Paleozoic strata; and Mesozoic to Cenozoic strata and volcanic rocks (Fig. 2a; HBGMR, 1993; Ge et al., 2005, 2007; Wu et al., 2003, 2011). The Xinghuadukou Complex is characterized by sillimanite gneiss, marble, felsic gneiss, amphibolite, and graphitic schist, which indicate it is a khondalitic sequence. It has traditionally been considered to be late Archean to Paleoproterozoic in age and metamorphosed from greenschist to amphibolite facies (HBGMR, 1993). However, new data indicate that granulite facies metamorphism occurred at ~500 Ma, whereas igneous zircon core ages from granulite facies rocks range from 601 ± 15 to 1637 ± 23 Ma (Zhou et al., 2011b). The granitoids in the area are of two ages: (1) Metamorphosed and deformed granites and pegmatites have emplacement ages of 460–500 Ma that are associated with the Xinghuadukou Complex (Ge et al., 2005, 2007; Wu et al., 2011); (2) Mesozoic younger undeformed granitoids are widespread throughout the region and represent a significant juvenile