Gondwana Research 23 (2013) 1342–1364

Contents lists available at SciVerse ScienceDirect

Gondwana Research

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

Middle Paleozoic convergent orogenic belts in western Inner Mongolia (China): framework, kinematics, geochronology and implications for tectonic evolution of the Central Asian Orogenic Belt

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ARTICLE INFO

Article history:
Received 15 December 2011
Received in revised form 19 May 2012
Accepted 23 May 2012
Available online 7 June 2012

Keywords:
Central Asian Orogenic Belt
Inner Mongolia
Paleo-Asian Ocean
Mélange, foreland basin

ABSTRACT

Based mainly on field geological observation and geochronologic data, six tectonic units have been recognized in western Inner Mongolia (China), including, from south to north: North China Craton (NCC), Southern Orogenic Belt (SOB), Hunshandake Block (HB), Northern Orogenic Belt (NOB), South Mongolia microcontinent (SMM), and Southern margin of Ergun Block (SME), suggesting that the tectonic framework of the CAOB in western Inner Mongolia is characterized by an accretion of different blocks and orogenic belts. The SOB includes, from north to south, fold belt, mélange, arc-pluton belt, and retroarc foreland basin, representing a southern subduction–collision system between the NCC and HB blocks during 500–440 Ma. The NOB consists also of four units: arc-pluton belt, mélange, foreland molasse basin, and fold belt, from north to south, representing a northern subduction–collision system between the HB and SMM blocks during 500–380 Ma. From the early Paleozoic, the Paleo-Asian oceanic domains subducted to the north and the south, resulting in the forming of the SOB and the NOB in 410 Ma and 380 Ma, respectively. This convergent orogenic system, therefore, constrained the consumption process of the Paleo-Asian Ocean in western Inner Mongolia. A double subduction–collision accretionary process is the dominant geodynamic feature for the eastern part of the CAOB during the early to middle Paleozoic.

1. Introduction

The Central Asia Orogenic Belt (CAOB) is a giant accretionary orogen between the Siberian craton and the North China and Tarim cratons and is characterized by a series of island arcs, forearc or backarc basins, ophiolitic belts and microcontinents from the Neoproterozoic to Mesozoic (e.g., Hsü et al., 1991; Mossakovsky et al., 1993; Sengör et al., 1993; Sengör and Natal'in, 1996; Badarch et al., 2002; Khain et al., 2002, 2003; Xiao et al., 2003; Buslovl et al., 2004; Safonova et al., 2004; Xiao et al., 2004; Li, 2006; Kröner et al., 2007; Demoux et al., 2009a; Xiao et al., 2009; Kröner et al., 2010; Xiao et al., 2010; Glorie et al., 2011; Kröner et al., 2011) and its massive generation of juvenile crust during the Phanerozoic (Hong et al., 1996; Han et al., 1997; Jahn et al., 2000a,b; Hong et al., 2004; Jahn et al., 2009; Han et al., 2011). Different evolutionary models have been suggested (Sengör et al., 1993; Mossakovsky et al., 1993; Windley et al., 2007).

Numerous recent regional studies show that the eastern segment of the CAOB is composed of a series of orogenic belts built from the Neoproterozoic to Mesozoic with several Precambrian microcontinental blocks between the Siberian and North China cratons (Fig. 1B; e.g., REFS). For example, a late Paleozoic active margin and an arc belt have been suggested in southern Mongolia (Yarmolyuk et al., 2005, 2008; Bayaraa et al., 2010; Blight et al., 2010), several Precambrian blocks and a huge late Pan-African metamorphic belt have been recognized in NE China (Zhou et al., 2009, 2010a, 2011), and a late Paleozoic Andean-style continental arc developed on the northern margin of the North China craton has been suggested (Zhang et al., 2007, 2009a). Western Inner Mongolia is part of the eastern segment of the CAOB, where the North China craton (NCC) is adjacent to the South Mongolian microcontinent (SMM). There are diverse ideas about the Paleozoic tectonic evolution. Xu and his co-workers (Xu and Chen, 1993, 1997; Xu and Charvet, 2010) suggested two opposite subductions and collisions during the middle Paleozoic to account for this evolution, emphasizing the late Devonian closure of the Paleo-Asian ocean along Ondor Sum in the south and Sunid Zuoqi in the north. Chen et al. (2000, 2009) suggested long-lived multiple southward and northward subductions from 530 to 250 Ma until a collision between the Tuva-Mongolia microcontinent and NCC ranging from 296 to 234 Ma, based on their zircon U–Pb ages, Hf

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doi:10.1016/j.gr.2012.05.015

and Nd–Sr isotopic data. Xiao et al. (2003, 2009) took SHRIMP data from 300 Ma to 250 Ma from ultramafic rocks in Inner Mongolia as evidence of the Paleo-Asian Ocean and considered that an end-Permian to mid-Triassic termination of the accretionary processes resulted in the final amalgamation of the CAOB. Jian et al. (2008, 2010) emphasized an early to mid-Paleozoic paired orogens and their evolution processes followed by a Permian intra-oceanic arc-trench system and a sequence of tectono-magmatic events from 299 Ma to 260 Ma responsible for the CAOB accretion, according to their detailed SHRIMP ages and geochemical data.

In this study we present the framework, kinematics and geochronology of a middle Paleozoic couple of convergent orogenic belts between the SMM and NCC in western Inner Mongolia of China, according to field observations and 1:50,000 geological mapping in key areas. We also present LA-ICPMS U–Pb ages in order to constrain the tectonic evolution of the belts. Based on these constraints and review of previous data, a tectonic evolutionary model of the convergent orogenic system and its implications for the tectonic evolution of the CAOB are also discussed.

2. Tectonic outline

Geologically, western Inner Mongolia belongs to the eastern part of the CAOB, which is characterized by the amalgamation of Paleozoic orogenic belts, Precambrian microcontinents and their margins (Fig. 1A and B). Six tectonic units can be identified in western Inner Mongolia, including the NCC, SMM, southern margin of the Ergun block (SME), Northern orogenic belt (NOB), Southern Orogenic Belt (SOB) and Hunshandake block (HB) between the NOB and SOB (Fig. 1C).

The NCC is characterized by an Archean-Paleoproterozoic metamorphic basement (Wan et al., 2011; Zhai and Santosh, 2011; Geng et al., 2012). It is called the Baoyintu Group in western Inner Mongolia, which includes quartzite, quartz rich micaschist, staurolite–kyanite schist intercalated with marble and plagioclase amphibole schist, dolomitic marble, staurolite–garnet mica schist, biotite bearing amphibole schist, leptynite and actinolite schist A whole rock Sm–Nd isochron age of 2485 ± 128 Ma from the plagioclase amphibole schist is interpreted as the age of the Baoyintu Group (IMBGMR, 1991; Xu et al., 2000).

The SMM is also called the Hutag Uul block or Totoshan Ulanul block in southwestern Mongolia (Badarch et al., 2002), extending ca. 600 km in E–W direction. It is represented in the Airgin Sum area, western Inner Mongolia, by the Airgin Sum Group, mainly composed of quartz rich micaschist, meta-volcanic rocks, meta-sandstone and marble (IMBGMR, 1991). An upper intercept age of 952 ± 8 Ma has been obtained from a two-mica gneissic granite of the Hutag Uul block (Yarmolyuk et al., 2005).

Extending from Erenhot in the west to Uliastai in the east, the 400 km long SME is composed of Ordovician and Devonian rocks, interpreted as the Paleozoic continental margin of the Ergun block (Xiao et al., 2003).

The HB may be considered as an independent tectonic unit between the NOB and SOB, unraveled by the Precambrian to early Cambrian detrital zircons from a mélange zone (see Sections 5.2). The HB sedimentary cover is represented by scattered outcrops of the Lower Paleozoic Ondor Sum Group and Upper Paleozoic limestone and clastic rocks (IMBGMR, 1991).

The NOB extends ca. 550 km from Xilinhot in the east to Airgin Sum in the west in our study area. Four units have been recognized (Fig. 2; Xu et al., 1994; Xu and Chen, 1997). Detailed observations of arc pluton have been reported by previous authors (Chen et al., 2000; Shi et al., 2004a,b, 2005; Jian et al., 2008; Chen et al., 2009).

The SOB extends from Ondor Sum, via Bater, to Tugurige, with a length of ca. 600 km from west to east. It has been defined based on detail studies of ophiolite, arc pluton, mélange, fold deformation and blueschist in the Ondor Sum and Bater areas (Shao, 1986; Hu et al., 1990; Tang, 1990; Tang and Zhang, 1991; Xiao et al., 2003; Jian et al., 2008). Four units have been recognized in the Tugurige area (Fig. 8; Xu et al., 2001b).

3. Northern orogenic belt (NOB)

The NOB consists of four units from north to south: arc-pluton complex, mélange, molasse basin, and fold belt (Fig. 1C). The arc-pluton complex extends discontinuously in Airgin Sum, Baiyanbaolidao, and Xilinhot areas from west to east. The mélange can be discontinuously traced in Airgin Sum, Naomuhunni and Honger areas, from west to east. The molasse basin occurs near the mélange or arc-pluton complex to the south of Abag and Baiyanbaolidao. The fold belt crops out in the southern area (Fig. 2). In this section, the tectonic units are firstly described, and the configuration and polarity of the NOB will be then discussed according to available geometric and kinematic features in the fold belt and mélange.

3.1. Arc-pluton complex: a review of data

3.1.1. Baiyanbaolidao area

Three tectonic units of the NOB have been recognized in Baiyanbaolidao area, to the south of Sonid Zuoqi, arc-pluton complex, mélange, and molasse basin (Fig. 2; Xu et al., 1994; Xu and Chen, 1997).

Arc-pluton complex consists of cumulate gabbros, gabbro-diorites, quartz diorites, tonalites, granites and occurs in a wide area of ca. 20 × 6 km. These rocks were affected by greenschist-facies metamorphism and locally developed foliations. Geochemically, Nd-Sr and *In-situ* zircon Hf isotopic analyses indicate that the complex represents a subduction-related arc magmatic belt (Chen et al., 2000, 2009) although a more complex evolution, from subduction to microcontinent accretion, has been proposed (Jian et al., 2008). Two U–Pb zircon ages of 418 and 439 Ma have been obtained from plagiogranite and granodiorite, respectively (Tang and Zhang, 1991) and another U–Pb zircon age of 418 ± 3 Ma from quartz diorite has been reported (Xu and Chen, 1997). Though two much younger ages of 309 ± 8 Ma and 310 ± 5 Ma have been interpreted as the forming age of the youngest arc (Chen et al., 2000, 2009), more detailed geochronological data from eleven samples of cumulate gabbro (482.5 ± 1.7 Ma), quartz diorite (475 ± 6 Ma, 479.7 ± 1.8 Ma), tonalite (479 ± 8 Ma, 464 ± 8 Ma, 471.3 ± 2.4 Ma), biotite monzonitic granite (423 ± 8 Ma), biotite granite (424 ± 10 Ma) and granite (422.8 ± 1.9 Ma, 427.3 ± 2.2 Ma, 440 ± 4 Ma) suggest an early to mid-Paleozoic arc-pluton complex (Shi et al., 2004b; Zhang et al., 2004; Shi et al., 2005; Jian et al., 2008).

3.1.2. Other areas

Jian et al. (2010) show that the SMM (Hutag Uul Block) in South Mongolia contains a metamorphic complex with orthogneiss (ca. 431 Ma) and amphibolite (ca. 477 Ma), suggesting the western continuation of the northern arc pluton complex. Yarmolyuk et al. (2005) report an age of 433 ± 12 Ma from one of the two-mica gneissic granites of this block. Several ages and geochemical results of biotite-plagioclase gneisses from the so-called Xilin Gol Complex in Xilinhot area, about 180 km to the east of Baiyanbaolidao, are reported. These gneisses, related to migmatization, yield detrital zircon ages of 437 ± 3 Ma and 452 ± 5 Ma and their geochemical features suggest a migmatization in a middle Paleozoic continental arc correlated with the arc pluton in Baiyanbaolidao area (Shi et al., 2003; Li et al., 2010a,b). The youngest zircon age is 406 ± 7 Ma, revealing the youngest arc magmatism (Xue et al., 2009). Ge et al. (2011) recently dated at ca. 411.0 ± 5.9 Ma (SHRIMP zircon age) the Lower Devonian volcanic rocks which unconformably overlay the Xilin Gol Complex, and at ca. 421 ± 1.8 Ma the granite which intrudes the Complex.