

A Special Issue Devoted to the Accretionary and Collisional Tectonics of the Altaids and its Metallogeny

Preface

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Altaids: The conception

The Altaids is tectonically sandwiched between the Baltica and Siberia cratons to the north and the Tarim and North China cratons to the south (Şengör et al., 1993). This huge orogen has been also called the Altaid collage (Yakubchuk, 2004), Central Asian Orogenic Belt (CAOB) (Jahn et al., 2000a), or Central Asian Orogenic System (Briggs et al., 2007). Long before these terms, the Altaids even had been called the Asian Foldbelt, Ural-Mongolian Foldbelt, or Ural-Amurian Foldbelt, mostly by the former Soviet Union scientists (Yakubchuk, 2004).

Since the advent of Plate Tectonics, “foldbelt” has been gradually abandoned in the international community. There are, however, some differences between the concept of the Altaids (Altaid orogenic collage) and the Central Asian Orogenic Belt and other terms, i.e., the Altaids does not include the Proterozoic orogens along the southern margins of the Baltica and Siberia cratons while the CAOB and other terms include these Proterozoic orogens (Windley et al., 2007). Although the Altaids and CAOB have been used in the international community widely, their southern part in China has been integrally called the Tianshan-Xingmeng orogen (He et al., 1994; Zhang and Wang, 1996; Li et al., 2011), Beifang (Northern China) orogen (Wu et al., 1998). In the meantime, other individual orogens are also used in the international community, such as the Altai, (West, or Western; East, or Eastern) Junggar, (West, or Western; East, or Eastern; North, Middle, South) Tianshan, Beishan, Alxa, Inner Mongolia, and Great Hing'anorogens (Gao et al., 1995; Li, 2006; Sun et al., 2007; Mao et al., 2012; Song et al., 2013; Liu et al., 2017; Zheng et al., 2017).

The term Altaids, firstly proposed by Eduard Suess in 1901, emphasizes a unique orogenic process very different from the classically conceived linear/arcuate, narrow orogens (Şengör et al., 1993). The Altaids was brought to

the international community again with the development of accretionary orogenesis in early 1990's, which records considerable continental growth in the Phanerozoic (Şengör et al., 1993; Li et al., 2012; Li et al., 2013; Ao et al., 2016). For the sake of avoiding misunderstanding in the international community, we generally use the Altaids for the entire orogenic collages in China and its adjacent areas, but keep the tradition of using individual orogen names since the Altaids covers a vast area in Central Asia (Feng et al., 1989; Zhou et al., 2009; Zheng et al., 2013; Kröner et al., 2014; Xiao et al., 2015; Yang et al., 2015; Xiao et al., 2018).

Long-lived, non-linear accretionary orogeny

The Altaids is the largest intact continental orogen in the world recording considerable Phanerozoic continental growth (Şengör et al., 1993; Jahn et al., 2000b; Zhao et al., 2006; Xiao et al., 2015, 2018). Tectonically, the Altaids is composed of three collages, i.e., the Tuva-Mongol orocline in the north, Kazakhstan orocline in the west, and the Tarim-Beishan-Alax-North China collages in the south (Şengör and Natal'in, 1996; Xiao et al., 2015, 2018).

From the aspect of orogenic process, the Altaids is an ideal field laboratory to conduct anatomy of the long-lived, non-linear accretionary orogeny (Şengör et al., 1993; Wang T et al., 2006; Wang B et al., 2011; Xiao et al., 2015, 2018). This type of orogeny is not like that in the Tethys, which may be described by collisional model (Yin and Nie, 1996; Hou et al., 2002). Long-lived, linear orogenic building components including the Japan-type and Mariana-type arcs and their attachments to small-scale micro-blocks forming the Alaskan-type or their variants, all play important roles in the architecture of accretionary orogenesis (Xiao et al., 2010). These long-lived, linear orogenic building components may have been oroclinally bent and rotated considerably with large-scale

rollback and retreat processes (Fig. 1) (Xiao et al., 2015, 2018).

Similar to the orogenesis in the Circum-Pacific and Terra Australis orogens (Cawood, 2005; Cawood and Buchan, 2007; Cawood et al., 2009), the Altaids shows archipelago paleogeography and involves long subduction-accretion history with multiple subduction polarities, large-scale extension, rollback, rotations and oroclinal bending of orogenic building components, which has been defined as the multiple accretionary orogenesis (Fig. 2) (Xiao et al., 2015, 2018).

The multiple accretionary orogenesis has been proposed

as one of the main mechanisms for the considerable Phanerozoic continental growth that has long been controversial. The large-scale rotations and oroclinal bending of orogenic building components trapped several oceanic domains, which also enhanced more chances for mid-ocean ridge-trench encounter, adding more juvenile materials to the crust (Xiao et al., 2015, 2018).

World-class metallogenic domain

The multiple accretionary orogenesis of the Altaids also generated huge amounts of mineral deposits in Central Asia (Qin et al., 2002; Seltnann and Porter, 2005;

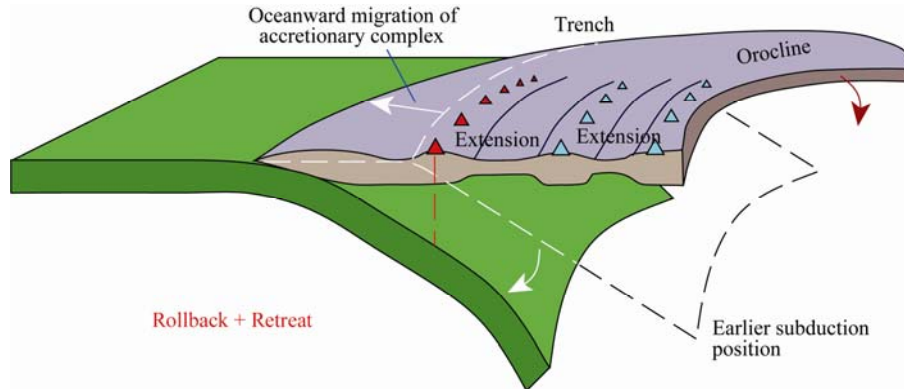


Fig. 1. Simplified diagram showing the Pz₂-T₁ extension with coeval forearc accretion in the Tuva-Mongol Orocline.

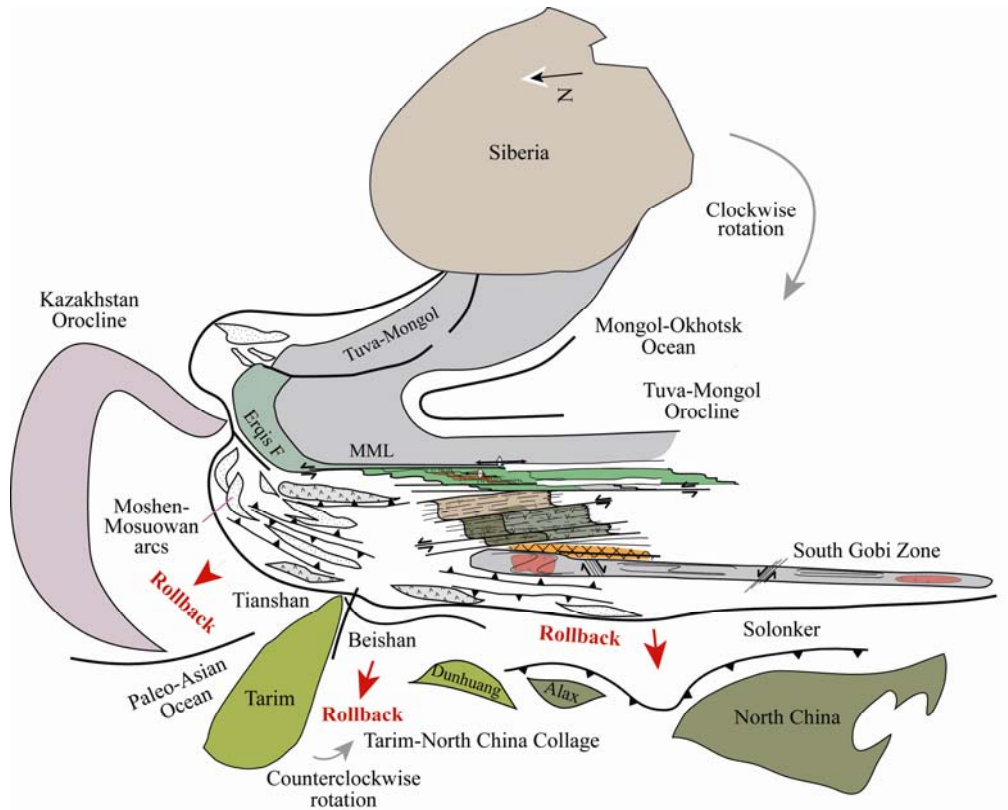


Fig. 2. Simplified tectonic reconstruction showing the Pz₂-T₁ rollback extension with multiple accretionary orogenesis in the Altaids (modified after Xiao et al., 2018). The north in Siberia is the present-day north.

Goldfarb et al., 2014). The Altaids bears hosts to numerous gold, silver, copper-molybdenum, lead-zinc, and nickel deposits of Late Proterozoic to Early Mesozoic ages, some of which are world-class mineral deposits (Qin et al., 2002; Seltnann and Porter, 2005; Goldfarb et al., 2014).

Various types of mineral deposits have been discovered and explored in the Altaids in which porphyry-type deposits are the most common representatives that are widely distributed. Widely distributed deposits. A series of porphyry-type Cu-(Mo)-(Au) deposits including some giant world-class deposits such as Kounrad, Aktogai, Kal'makyr, Oyu Tolgoi and Chalukou occur in the Central Asian metallogenic domain (Yakubchuk et al., 2001; Qin et al., 2002; Seltnann and Porter, 2005; Choulet et al., 2011; Goldfarb et al., 2014; Deng et al., 2017; Gao et al., 2018).

Unlike the metallogenic processes in the Tethys where the formation and preservation of mineral deposits are mostly related to collisional and/or post-collisional orogenic processes (Hou et al., 2013), the metallogeny in the Altaids is more closely related to the long-lived multiple accretionary orogenesis (Qin et al., 2002; Mao et al., 2004; Seltnann and Porter, 2005; Xiao et al., 2008; Goldfarb et al., 2014; Gao et al., 2018).

Introduction to the special issue

Recently, there have been two major projects launched on the tectonic evolution and deep structures with emphasis on the geophysical exploration down to the 3000 metre deep structure and formation mechanism of mineral deposits. Together with some projects from the National Science Foundation of China, tremendous progress has been made regarding the tectonics and metallogeny of the Altaids.

In this special issue of *Acta Geologica Sinica* (English Edition), we have assembled 24 papers that contribute to a better understanding of the accretionary and collisional tectonics of the Altaids and its metallogeny. These papers deal with the Altaids from the west to the east geographically and cover aspects from geology to metallogeny scientifically.

The Altai-Junggar-Tianshan collage in southern Altaids is an important metallogenic domain in Central Asia that contains world-class copper-iron-nickel deposits. Xiao et al. (2019-in this issue) presented a brief introduction to the project on the western part of the Southern Altaids, entitled "The deep structure and metallogenic processes of the North China accretionary metallogenic systems". This project mainly focuses on the deep structure and metallogenic background of the Altai-Junggar-Tianshan collage by integrated studies on field geology, structural mapping, geochemistry and geophysical exploration. Multiple new geological and geophysical methods will be applied to make transparency of the deep structures along the Altai-Tianshan traverse and the Kalatongke and Kalatage ore clusters.

Based on zircon U-Pb ages and Hf isotopic data of Carboniferous highly fractionated I-type granites from the Kalamaili Fault Zone, NW China, Song et al. (2019-in this issue) suggested that these high-K granitoids were derived from melting of heterogeneous crustal sources or through

mixing of old continental crust with juvenile components and minor AFC (assimilation and fractional crystallization). They were probably emplaced in a post-collisional extensional setting and suggested vertical continental crustal growth in the southern Altaids.

Huo et al. (2019-in this issue) reported results of zircon U-Pb ages and systematic geochemical data for early Permian Baleigong granites in the western part of the southwestern Tianshan Orogen. The I-type granitic magmatism was generated by partial melting of the continental crust, possibly triggered by underplating of basaltic magma in a collisional tectonic setting. This supports that the closure of the South Tianshan Ocean was completed prior to the Permian and was followed by collision between the Tarim Block and the Central Tianshan Arc Terrane.

A great number of the Devonian to the Triassic magmatic Cu-Ni deposits are distributed across the Tianshan-Xingmeng Orogenic Belt, from Tianshan Mountains in Xinjiang in the west, to Jilin in eastern China in the east. Han et al. (2019-in this issue) summarized the metallogenic setting, deposit geology and mineralization characteristics of each deposit in this region. Geochronologic data of Cu-Ni deposits indicate that, from the west to the east, the metallogenic ages in the Tianshan-Xingmeng Orogenic Belt changed with time, namely, from the Late Caledonian (~440 Ma), through the Late Hercynian (300–265 Ma) to the Late Indosinian (225–200 Ma). Such variation could reflect a gradual scissor type closure of the paleo Asian ocean between the Siberia Craton and the North China Craton from west to east.

Li J. G. et al. (2019-in this issue) collected samples from typical natural sections, boreholes, and the surficial sediments of the Quaternary sediments in the Yili Basin. The surficial sediments of the Huocheng area were mainly formed in the Late Pleistocene by using the optically stimulated luminescence (OSL) and electronspin resonance (ESR) dating methods. The Huocheng area was uplifted synchronously with the Tianshan Mountains during the last stage of the Late Pleistocene, causing the desert facies sediments to be superimposed on the former paleo-lake sediments.

The Solonker suture zone has long been considered to mark the location of the final disappearance of the Paleo-Asian Ocean in the eastern Altaids. Li Y. L. et al. (2019-in this issue) reported integrated whole-rock geochemistry and zircon U-Pb ages of Silurian-Permian sedimentary rocks in central Inner Mongolia, China.

Combined with studies from Wang K. et al., it is concluded that (2019-in this issue) study, it is concluded that Carboniferous to early Permian (~326–275 Ma) northward subduction of the Paleo-Asian oceanic crust led to the formation of the mafic magmatism in the Baolidao arc zone. Early Paleozoic subduction until ca. 381 Ma, and the renewed subduction during ca. 310–254 Ma accompanied by the opening, and closure of a back-arc basin during ca. 298–269 Ma occurred in the northern accretionary zone. In contrast, the southern accretionary zone documented early Paleozoic subduction until ca. 400 Ma and a renewed subduction during ca. 298–246 Ma. The final closure of the Paleo-Asian ocean therefore lasted at least until the early Triassic and ended with the

formation of the Solonker suture zone.

Wang S. J. et al. (2019-in this issue) identified Permian volcanic rocks in the Bainaimiao Arc Belt of the southern accretionary zone, Inner Mongolia. Composition of zircon and isotopes indicate that the Bainaimiao Arc Belt and North China Craton have become an integrated whole before 278 Ma though they have different basements. This supports that the Paleo-Asian Ocean has not closed yet until 258 Ma.

There is a controversy regarding the amalgamation of Xing'an and Songnen Blocks along the Hegenshan-Heihe Suture in the eastern Altaids. Zhang L. et al. (2019-in this issue) performed detailed study on Early Permian A-type granites in the Zhangdaqi area. These A-type granites together with coeval bimodal volcanic rocks along the Hegenshan-Heihe Suture indicate that this suture closed in the late Early-Carboniferous.

Zhang Y. J. et al. (2019-in this issue) described a new species of *Coniopterismoguqiensis* sp. nov. preserved as a fragment with fertile and sterile pinnules from the Middle Jurassic Wanbao Formation in Moguqi Town of Inner Mongolia. The fern genus *Coniopteris* usually suggests a warm and humid environment, which is consistent with the palaeoclimatic conditions of petrified wood and megafossil plants, providing new material for understanding the evolutionary trend and classification of *Coniopteris*.

The early Mesozoic marked an important transition from collisional orogeny to post-orogenic extension at the northern margin of the North China Craton. Chen J. S. et al. (2019-in this issue) undertook zircon U-Pb dating and systematic geochemical analyses of early Mesozoic granitic rocks in the Chifeng area. Overall, the early Mesozoic tectonic evolution of the Chifeng area can be divided into three main stages: (1) closure of the Paleo-Asian Ocean and extension related to slab break-off during the Early Triassic; (2) continuous collisional compression during the Middle Triassic; and (3) post-orogenic extension during the Late Triassic.

Shi et al. (2019-in this issue) reported the petrography, geochemistry and geochronology data of Neoarchean charnockites at the north margin of the North China Craton. This study indicates these charnockites were formed by the crystallization differentiation of the upwelling of mantle-derived shoshonitic magma, with the addition of lower crust material.

Paleoproterozoic granitoids are an important constituent of the Jiao-Liao-Ji Belt (JLJB). Zhu et al. (2019-in this issue) reviewed the field occurrence, petrography, geochronology, and geochemistry of Paleoproterozoic granitoids on Liaodong Peninsula, northeast China. The Paleoproterozoic granitoids can be divided into pre-tectonic (~2.15 Ga; peak age=2.18 Ga) and post-tectonic (~1.85 Ga) granitoids.

Li C. H. et al. (2019-in this issue) focused on the U-Pb geochronological studies of detrital zircons from Bayan Obo Group exposed in the Shangdu area, Inner Mongolia, aiming to understand the paleoposition of North China Craton (NCC) in Rodinia. This study proposed that the NCC might receive detritus from Baltica during 1560–1350 Ma and had affinity with Laurentia and Amazonia at ~0.9 Ga in Rodinia. Baltica, Amazonia and Laurentia might be

potential provenances for non-NCC detritus in Bayan Obo Group.

Chen Z. X. et al. (2019-in this issue) carried out detrital zircon U-Pb dating of Late Paleozoic sedimentary rocks in the Songliao and Jiamusi blocks. It is proposed that the oceanic basin between the Songliao and Jiamusi blocks should have been connected before Late Permian and reopened during Late Permian to Late Triassic.

The Zhalantun terrane from the Xing'an massif, northeast China, was considered as Proterozoic basements. Qin et al. (2019-in this issue) identified Early Paleozoic magmatism in this terrane. Combined with ancient zircon ages and newly reported ~2.5 Ga and ~1.8 Ga granites from the south of the Zhalantun, therefore, the Precambrian rocks probably once exposed in the Zhalantun while they were re-worked and consumed during later long tectonic evolutionary history, resulting in absence of Precambrian rocks in the Zhalantun.

Zhang Q. et al. (2019-in this issue) found provenance transformation from the Yangjiagou Formation (ca. 245 Ma) to the Lujiatun Formation (ca. 219 Ma) in the Jiutai Area, NE China. Based on the provenance analysis of these two formations, the final closure time of the Paleo-Asian Ocean in this area is constrained as from the early Middle Triassic (ca. 245 Ma) to the middle Late Triassic (ca. 219 Ma).

The calcite mylonites in the Xar Moron-Changchun shear zone show a significant dextral shearing characteristic. Liang et al. (2019-in this issue) carried out macro-and-micro structural, textural fabrics and deformation studies on these calcite mylonites in this area. This E-W large-scale dextral strike-slip movement is a consequence of the eastward extrusion of the Xing'an-Mongolian Orogenic Belt, and results from far-field forces associated with the Late Triassic convergence domains after the final closure of the Paleo-Asian Ocean.

Dong et al. (2019-in this issue) represented geochronology and geochemistry of Early Cretaceous granitic plutons in the Xing'an Massif, NE China. Combined with the petrological and geochemical features, these plutons show highly fractionated I-type granite affinity, probably associated with the break-off of Mudanjang Ocean.

Wang C. Y. et al. (2019-in the issue) gave a simple review on geology, mineralization, fluid inclusion and stable isotope of the Early Cretaceous Sn and associated metal deposits in the Southern Great Xing'an Range, NE China. This study developed a metallogenic model for Early Cretaceous Sn and associated metal deposits in the Southern Great Xing'an Range.

Zhang L. Y. et al. (2019-in this issue) carried out a comprehensive study on Early Cretaceous andesites from the Northern Great Xing'an Range, NE China, using zircon U-Pb dating and geochemical and Hf isotopic analysis to investigate their petrogenesis and tectonic setting. It can be concluded that these adakitic rocks were affected by the Mongol-Okhotsk tectonic regime, forming in a transition setting from crustal thickening to regional extension thinning.

Cui et al. (2019-in this issue) discovered a suite of arkose beneath the marine-land interbedded strata, which overlies unconformably on the Permian granite in the

eastern margin of the Jiamusi massif. The results of detrital zircon U-Pb dating of Nanshuangyashan Formation, combined with regional analyses, indicate that the closing of Mudanjiang ocean and Panthalassa ocean possibly existed from the Early Permian to the Late Triassic.

The NE-striking Jiamusi-Yitong fault zone (JYFZ) is the most important branch in the northern segment of the Tancheng-Lujiang fault zone. Wen et al. (2019-in this issue) presented microstructural observation and the $^{40}\text{Ar}/^{39}\text{Ar}$ age data of muscovite from ductile shear zones. The initiation of the JYFZ in the late Jurassic is related to the speed and direction of oblique subduction of the west Pacific Plate under the Eurasian continent and is responsible for collision during the Jurassic period.

Lu et al. (2019-in this issue) carried out in situ LA-ICPMS trace elements and sulfide S-Pb isotopic analyses on stratiform ore bodies of the Dongfengnanshan copper polymetallic deposit in the Yanbian area, NE China. The stratiform ore bodies of the Dongfengnanshan deposit belong to the VMS-type and have closely genetic relationship with the early Permian marine volcanic sedimentary rocks.

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