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Deep Structure and Metallogenic Processes of the Altai-Junggar-Tianshan Collage in Southern Altaids

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Abstract: The Altai-Junggar-Tianshan collage in southern Altaids is an important metallogenic domain in Central Asia that contain world-class copper-iron-nickel deposits. As an accretionary-type metallogenic system, the metallogenic processes of the Altai-Junggar-Tianshan collage is essential in understanding the genetic mechanism of ore deposits in general. Here in this paper we present a brief introduction to the project on the western part of the Southern Altaids, entitled “The deep structure and metallegenic 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 from field geology, structural mapping, geochemistry and geophysical exploration. Multiple new geological and geophysical methods will be applied to make transparency of the Kalatongke and Kalatage ore clusters. This will update our understanding of the geodynamic processes of metallogenesis and lead to the development and foundation of new metallogenic theories in accretionary orogens.

Key words: accretionary orogen, metallogenesis, deep structure, northern Xinjiang, Altaids

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1 Introduction

The Altaids (or Central Asian Orogenic Belt, CAOB), sandwiched between the Baltica Craton to the northwest, the Siberian Craton to the northeast, and the Tarim and North China cratons to the south, is the largest accretionary orogenic belt and one of the three major metallogenic domains in the world (Şengör et al., 1993; Yin and Nie, 1996; Jahn et al., 2000; Jahn et al., 2004; Mao, 2005; Han et al., 2007; Windley et al., 2007; Wu et al., 2007; Yang et al., 2007; Abrajevitch et al., 2008; Xiao and Kusky, 2009; Zhou et al., 2009; Wang et al., 2011; Bazhenov et al., 2012; Gao et al., 2013; Zheng et al., 2013; Goldfarb et al., 2014; Yi et al., 2015; Zhang and Jin, 2016; Liu et al., 2017a, b; Song et al., 2017; Wan et al., 2017; Windley and Xiao, 2018). According to the paleobiogeographic and tectonic data, it can basically be divided into three large collage systems: the Kazakhstan Collage System in the northwest, the Mongolia Collage System in the northeast and the Tarim-North China Collage System in the south (Xiao et al., 2015) (Fig. 1).

With the implement of a series of science and technology projects during the last two decades, there has been significant progress in understanding the magmatism, deformation, crustal structure, orogenic architecture and metallogenic background in the Altaids (Li, 1995; Yin et al., 1998; Hu et al., 2000; Yakubchuk et al., 2001; Qin et al., 2002; Li et al., 2003; Wang et al., 2003; Shu et al., 2004; Zhang et al., 2005; Yuan et al., 2007; Chen et al., 2010; Yuan et al., 2010; Jiang et al., 2012; Tang et al., 2012; Goldfarb et al., 2014; Kröner et al., 2014; Mao et al., 2014; Ao et al., 2016; Gao et al., 2018). The tectonic model of multiple subduction and accretionary processes during the Palaeozoic to early Mesozoic and the concept of accretionary metallogenic system have been proposed (Xiao et al., 2015; Xiao et al., 2004). Despite of these progress, there are many issues that need further investigations. These include the deep structure of the orogenic belt, the metallogenic mechanism of different types of metallogenic systems, and the crustal nature of various tectonic units of the Altaids. Moreover, the current depth of exploration for typical ore deposits in northern Xinjiang and adjacent areas is only 1000 m or even less. These have hampered us from better understanding metallogenesis, improving exploration depth and searching new deposits in Xinjiang. Therefore, two new projects have been launched to carry out research on the deep structure and metallogenic processes of the western and eastern parts of the Southern Altaids. In this paper, we present a brief introduction to the project on the western part of the Southern Altaids, entitled “The deep structure and metallegenic processes of the North China

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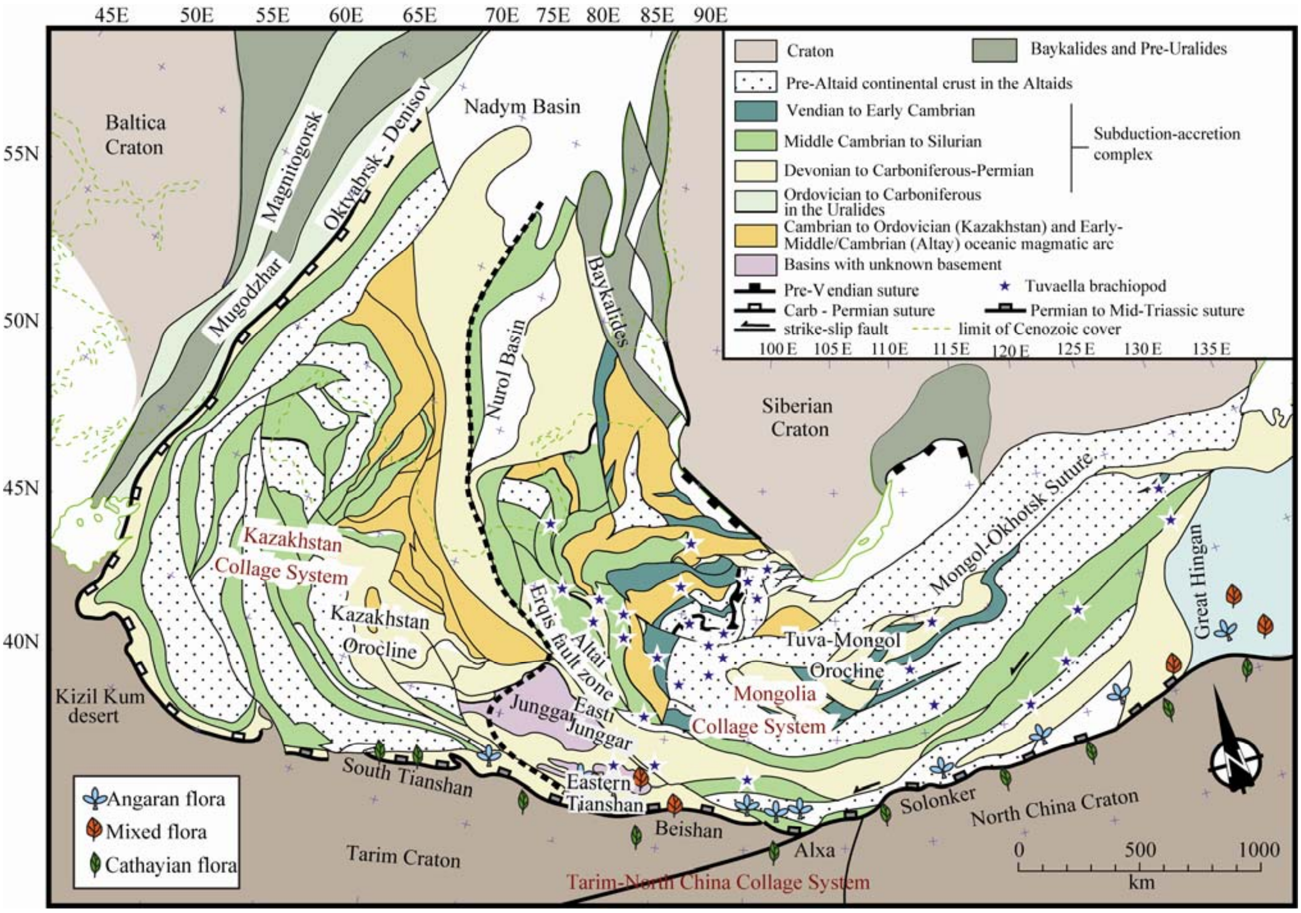

Fig. 1. Tectonic map of the Altaids showing the major components constituting this huge orogenic system and the distribution of three large collage systems (modified from Şengör et al., 1993; Xiao et al., 2015).

accretionary metallogenic systems", with research emphasis on the deep structure and metallogenic processes of the Altai-Junggar-Tianshan collage.

2 Scientific Issues

The Altai-Junggar-Tianshan collage in southern Altaids is located in the triple junction region of the three collage systems. It contains large-scale metallogenic systems that play a key role in assuring mineral resources supply in China (Mao et al., 2008). Compared to other orogenic belts and metallogenic systems worldwide, the tectonics and metallogenesis of the Altai-Junggar-Tianshan collage in the southern Altaids have several important characteristics. (1) The Altai-Junggar-Tianshan collage has undergone multi-stage crust-mantle interaction and diverse superimposed metallogenic processes during the multiple subduction and accretionary processes of orogenic consolidation. (2) Large-scale magmatism during tectonic regime transition is key factor in controlling the concentration of ore-forming elements. (3) The deep structure, magmatic mechanism, massive element migration and concentration, metallogenic end-effect and shallow structure are the key to understanding the metallogenic processes and creating new metallogenic theory. (4) Several large ore deposit clusters exist in the Altai-Junggar-Tianshan collage, and the 3000 m transparentizing of these ore deposit clusters becomes the breach of mineral resource evaluation and ore prospecting.

The key scientific issue concerning the metallogenic systems in Altai-Junggar-Tianshan collage is how the deep geological structures control the metallogenic processes. This includes three specific issues: (1) the deep structure and crust-mantle interaction dynamics of the metallogenic system; (2) 3-D structure, spatiotemporal evolution and key controlling factors of the metallogenic system; (3) the end-effect of major metallogenic systems and orebody location mechanism.

3 Research Contents

Concentrating on the key scientific issue "How the deep structure controls the metallogenic processes in Altai-Junggar-Tianshan collage in southern Altaids", the major research contents include the following aspects.

3.1 Geophysical prospecting and explanation of deep structures

Integrated geophysical prospecting (including deep seismic reflection/refraction, short-period seismic dense array, passive broadband seismic array, magnetotelluric sounding etc.) will be carried out along an 800 km-long profile from the Altai (Fuyun city) in the north to Tianshan (Tuwu south) in the south, crossing all the major tectonic units in the Altai, East Junggar and Eastern Tianshan (Fig. 2). In addition, geophysical exploration along three transverse sections (north, central and south transverse section in Fig. 2) will also be carried out. This will help us to obtain the detailed structure of crust and upper mantle and their deformation features, the superposition relationship of plate boundaries and the geometry of deeply subducted slabs. Meanwhile, with the development of geophysical inversion methods, the deep crust material composition and its rheological characteristic, and the depth and composition of magma will be deduced. The geodynamics numerical simulation research will be carried out to infer the relationship between magmatism and shallow geological structure during tectonic regime transition, and the arc amalgamation and ridge-trench interaction during multiple subduction-accretion processes. The detailed processes of accretionary orogeny will be reconstructed based on field observation and deep structure prospecting. The intracontinental orogenic processes and their tectonic reworking on preexisting magmatic rocks, orebody and deformation will be discussed based on the geophysical data.

3.2 The metallogenic processes and their end-effect

Different types of metallogenic systems such as volcanic massive sulfide deposit, porphyritic deposit, orogenic type deposit, mantle-derived magmatic deposit and high-temperature magmatic hydrothermal deposit may be generated in different evolution stages and different tectonic settings during the long-lived evolution of the southern Altaids. Concentrating on these diverse metallogenic systems, the following research work will be carried out. (1) Geodynamic setting for metallogeny and lithospheric structure. These include regional tectonic units and their boundaries, paleogeography of the ancient ocean-land, accretionary history, crust-mantle interaction, composition, structure and evolution of lithosphere, tectonic-magmatism-hydrothermal relationship and their correlation to metallogenic systems. (2) The crustal structure of ore-concentrated areas. This includes the basement constitution and its tectonic affinity, the nature of sedimentary cover and environment, and the volcanic eruption cycles. (3) The spatial-temporal structure of metallogenic systems. This includes the 3-D structure of orebodies, the relationship between orebodies and stratum, the mineral constitution and their intergrowth relationship of orebodies, metallogenetic period and stage, the chemical features of orebodies, fluid inclusions, host rock and mineralization ages, and the coupling mechanism of structure, fluid (magma), and ore-forming elements. (4) Ore-forming factors and end-effect. These include tectonic setting and rock assemblages at regional scale, fault, fold, shear zone and ore-forming fluid at metallogenic belt scale, and contact zone, wall rock alteration and mineralization zoning in individual ore deposit.

Through the study of deep structure, material composition, ore deposit types, ore-forming processes and mechanism of five different metallogenic systems, combined with the end-effect of mineralization, metallogenic models at different scale will be reconstructed. This will enhance our understanding of the relationship between metallogeny and major geological events during orogenesis, and lead to the foundation of metallogenic theory in accretionary orogen.

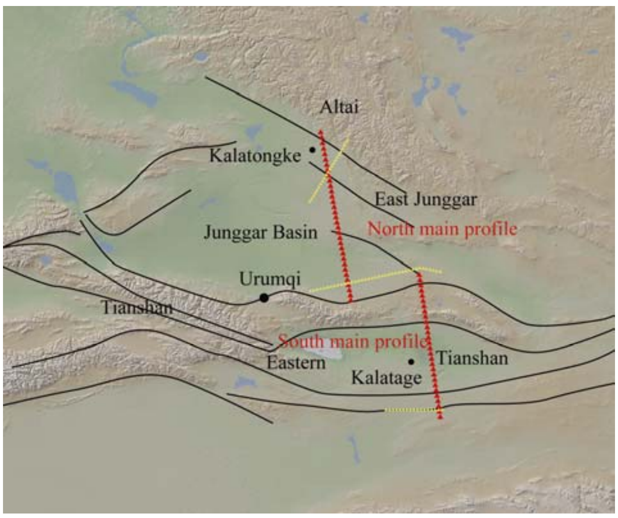

Fig. 2. Main profile and transverse sections for integrated geophysical prospecting.

3.3 Transparentizing of ore-concentrated area and orebody location mechanism

The Karatongke and Kalatage ore concentration areas are two major ore deposit clusters in the Altai-Junggar-Tianshan collage in northern Xinjiang. The Karatongke is an ore concentration of copper and nickel deposits, while the Kalatage is an ore concentration of volcanic massive sulfide (VMS) type, porphyritic type, hydrothermal vein type, and magmatic Ni-Cu sulfide deposits. These two deposit clusters are the major target for transparentizing and orebody location. The methods include 3-D seismic exploration, transient electromagnetic prospecting, controllable source audio magnetotelluric (CSAMT) method, short-period seismic dense array, passive broadband seismic array, high precision magnetic survey, gravity survey, magnetotelluric sounding (MT, dot spacing of 1000 m), and surface-to-borehole induced polarization method. Three-dimensional geophysical joint inversion will be carried out by optimizing new technologies (gravity, magnetic, electronical, seismic methods) and routine method. These methods combined with geochemical exploration method, will be applied to the deep exploration for the Kalatongke and Kalatage ore concentration areas. The accuracy of detection will be improved by the development of new techniques for multivariate data processing. Visual 3-D geological-geophysical-geochemical model will be built based on the metallogenic model and ore-controlling structures, leading to the transparentizing of geological structures and orebodies in the Kalatongke and Kalatage ore deposit clusters. Based on the study of regional metallogenic background, fault, ore-bearing rock, mineralization, alteration, ore-forming fluid and preservation conditions, the mechanism of orebody location will be discussed.

3.4 Metallogenic dynamic processes and mechanism of deep geological processes

The first-hand data will be obtained by detailed field geological observation, structural analysis, and large-scale geological mapping. The geometry, kinematics, stress and deformation mechanism for both ductile and brittle deformation will be determined by detailed structural analysis. The spatial-temporal coordinates of key geological events will be constructed by detailed study of accretionary processes of the Altai-Junggar-Tianshan collage, including regional tectonic units and their boundaries, ancient ocean-land configuration, crust-mantle interaction, composition and structure of lithosphere, regional structure and magmatism. The mechanism of exchanges of mass and energy during crust-mantle interaction and their effect on metallogeny will be investigated. A comparative study of the Altai-Junggar-Tianshan collage with its adjacent regions and north American accretionary orogens will be carried out. An integration of the results of five different metallogenic systems, the geological prospecting and deep processes will reveal the deep structure and dynamic processes of the metallogenic systems. This will ultimate lead to the develop and foundation of new metallogenic theory of accretionary orogenic belts.

4 Subjects

According to the scientific issues and research contents, the project is divided into 6 subjects. The detailed research objectives and contents for each subject are described in the following paragraphs. The relationship between the research contents and subjects is shown in Fig. 3.

4.1 Subject 1: Three-dimension structure and orebody location mechanism for massive sulfide metallogenic systems

This subject mainly focuses on the volcanism, metamorphism, deformation and tectonic evolution of the Chinese Altai and Kalatage-Xiaorequanzi metallogenic belt in Chinese Tianshan. The research contents of this subject include: (1) Petrogenesis of ore-bearing volcanic rocks and metallogenic geodynamic background; (2) Spatiotemporal evolution of metallogenic systems and end -effect of ore-forming processes; (3) Transparentizing of ore deposit clusters and orebody location prediction; (4) Comparison of ore deposit clusters and regional mineralization regularity; (5) Sedex-type Pb-Zn metallogenic system in the Sayram Lake area.

4.2 Subject 2: Spatial-temporal evolution and ore-forming processes of porphyritic metallogenic systems

The research contents of this subject include: (1) Metallogenic background and crust-mantle interaction of key ore deposit clusters; (2) The formation mechanism and preservation conditions of porphyritic metallogenic

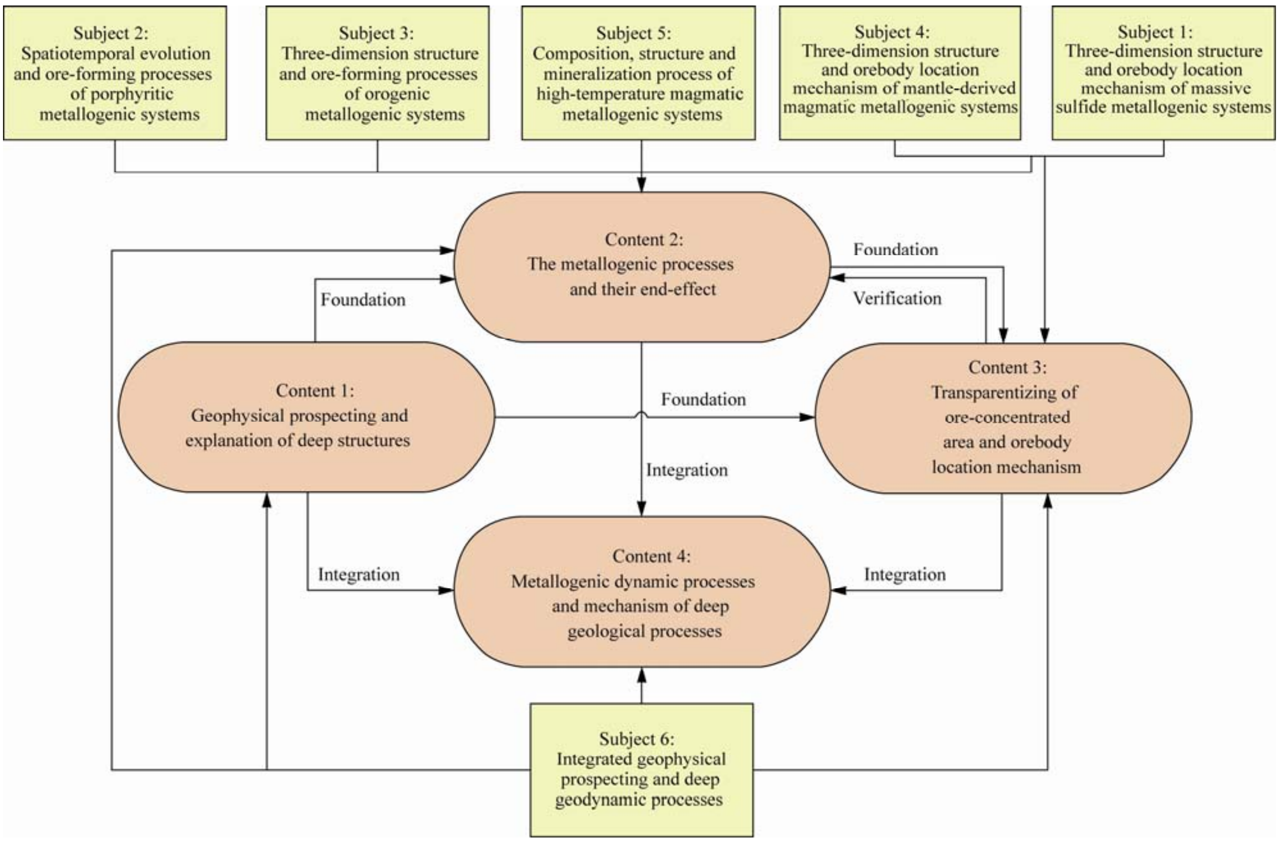

Fig. 3. The relationship between the research contents and subjects

systems; (3) Spatiotemporal evolution of material and structure of the metallogenic systems; (4) Metallogenic theoretical model and prospecting criteria.

4.3 Subject 3: Three-dimension structure and ore-forming processes of orogenic metallogenic systems

The research contents of this subject include: (1) Regional and ore-district geology; (2) Structural analysis of ore field; (3) Geological and geochemical studies of ore deposits; (4) Three-dimension model for orogenic metallogenic systems; (5) Deep mineral resource prediction in mining area.

4.4 Subject 4: Three-dimension structure and orebody location mechanism of mantle-derived magmatic metallogenic systems

The research contents of this subject include: (1) The metallogenic mechanism of major ore deposits; (2) Geological model for ore prediction; (3) Three-dimension geological structure and 3000 m "transparentizing" of typical ore deposit clusters; (4) Integrated minerals positioning predication.

4.5 Subject 5: Composition, structure and mineralization process of high-temperature magmatic metallogenic systems

The research contents of this subject include: (1) The high-resolution spatial and temporal distribution of granitoids; (2) The magma sources and petrogenesis of granitoids; (3) Relationship between tectonic, magmatic and metallogenic geodynamic processes; (4) Anatomy of typical ore deposits and regional metallogenic model; (5) Synthetic studies of petrogenesis and mineralization of granitoids.

4.6 Subject 6: Integrated geophysical prospecting and deep geodynamic processes

The research contents of this subject include: (1) Features, types and genesis of accretionary metallogenic systems; (2) Accretionary orogenic processes, crust-mantle interaction and metallogenic processes; (3) Theoretical systems for accretionary metallogenic systems; (4) Comparative study of the accretionary process of Altai-Junggar-Tianshan collage with other typical accretionary orogens worldwide; (5) Comprehensive geophysical research of 800 km-long profile from Chinese Altai to Tianshan.

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