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# Mineralogical and isotopic studies of base metal sulfides from the Jiawula Ag–Pb–Zn deposit, Inner Mongolia, NE China

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ABSTRACT

The Jiawula Ag–Pb–Zn deposit is located in the northern part of the Da Hinggan Mountains metallogenic belt in the eastern section of the Central Asian Orogenic Belt. Sphalerite, galena, pyrite, chalcopyrite, and arsenopyrite are the major sulfide minerals occurring in this deposit. Here we report results from electron probe micro-analysis (EPMA), thermoelectricity, and sulfur isotope studies of the constituent silver minerals and sulfide phases of the Jiawula deposit. Petrographic observations and EPMA study reveal abundant silver mineralization in the ore, especially within sphalerite and galena. Discrete grains of silver minerals (including argentite, pyrargyrite, and canfieldite) and isomorphism in silver-bearing sulfides are identified. Silver and tellurium contents in galena are relatively high and show interrelationship. Significant substitution of S by Te in the galena lattice facilitates silver entering the galena structure, which might have been promoted by relatively low $lgfS_2$. The thermoelectric coefficient of pyrite shows a marked gradient from N-type to P-type from pre- to post-metallogenic stages. Pyrites in Jiawula are enriched in Co and As and in the absence of Ni, displaying features typical of epithermal deposits. The isotopic data present a close relationship between the sulfur source and magmatism.



## 1. Introduction

The Da Hinggan Mountains in the eastern section of the Central Asian Orogenic Belt is well known for its variety of metallic mineralization (Mao et al., 2005, 2014; Chen et al., 2011; Li et al., 2012; Zhai et al., 2013a, 2014). The Jiawula large-scale Ag–Pb–Zn deposit is located in the northern part of the Da Hinggan Mountains metallogenic belt, which forms the extension of the well-known Russian–Mongolian polymetallic metallogenic belt.

Previous studies on the Jiawula deposit mainly focused on the deposit geology (Zeng, 2010), geochemistry (Zhao et al., 2005), and metallogenic fluid characteristics (Wu et al., 2010; Zhai et al., 2013a,b). The geodynamic setting of the Jiawula deposit has been correlated with Mesozoic Mongolia–Okhotsk post-collisional orogeny during the Early Cretaceous (Li et al., 2014). However, detailed investigations on the mineralogy and its relation to ore genesis, especially the mineral chemistry of sulfides, have not been attempted for this major ore deposit. A precise understanding of the precious metals in sulfides is essential to optimize metal recovery, improve metallurgical techniques, and gather more information on ore-forming processes (Costagliola et al., 2003).

The properties of pyrite occurring in gold deposits have been widely studied including crystal structure (Li et al., 1996; Abraitis et al., 2004), chemical composition (Li et al., 1994, 1996; Abraitis et al., 2004; Cook et al., 2009a; Yan et al., 2012, 2013), and thermoelectricity (Chen et al., 1987; Li et al., 1994, 1996, 2013; Abraitis et al., 2004; Cao et al., 2008; Chen et al., 2010). However, as a common mineral in Ag-metallogenic deposits, its geochemical characteristics and implications on ore genesis are still unclear.

In this paper, we use a multiparametric approach including the thermoelectric coefficient of pyrite and geochemistry of Ag minerals as well as the associated sulfides (silver-bearing and silver-free) in the Jiawula deposit with a view to identify the thermoelectrical and compositional properties. Our study provides important insights into the ore-forming conditions in Ag-metallogenic systems.

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## 2. Regional geology

The Da Hinggan Mountains are located in the eastern section of the Central Asian Orogenic Belt (CAOB) which marks the boundary between the Siberian, Tarim, and North China Cratons (Fig. 1a). The Jiawula deposit, constituting a part of the Ergun orogenic belt, is located in the northern extremity of the Da Hinggan Mountains and to the NW of the Derbugan fault (Fig. 1b). The Ulaan-Jiawula metallogenic province in eastern CAOB is one of the densely distributed regions of large-scale deposits in the world, including 44 superlarge and large deposits (Nie et al., 2015).

Two major tectono-stratigraphic units have been recognized in this region: a pre-Jurassic metamorphic massif and a Mesozoic volcano-sedimentary sequence (Nie et al., 2015). The local stratigraphy of the Da Hinggan Mountains region is dominated by Jurassic successions and to a lesser extent by Cretaceous rocks (Fig. 1c). High concentrations of metallic mineralization including Cu, Ag, Pb, Zn, and Mo occur within intermediate-mafic volcanic rocks of the Tamulangou Formation and sandstone and conglomerate of the Nanping formation (Zhai et al., 2013b).

The Da Hinggan Mountains record strong superimposition and transition between the EW-trending Palaeozoic Paleo-Asian domain and SSW–NNE-trending Mesozoic–Cenozoic western Pacific tectonic/metallogenic domain. The main tectonic events of this region belong to two distinct stages: (i) NS-trending compression between the Siberia Craton and the North China Craton prior to Early Jurassic, and (ii) oblique subduction to the northwest of the Pacific Plate toward the east of the Eurasian continent beginning in the Middle–Late Jurassic (Mao et al., 2005, 2014; Liu et al., 2014). The NE and NW trending conjugate faults formed during Pre-Mesozoic, and played an important role both in the development of the regional structural architecture and in controlling the magmatic and metallogenic activities (Hu et al., 1998).

The widespread magmatism in this region represented by both plutonic and volcanic suites can be divided into four stages: late Hercynian, Indo-Sinian, early Yanshanian, and late Yanshanian (Wu et al., 2010; Zhai et al., 2013b). Hypabyssal intrusions consisting of granite porphyry, quartz porphyry, and quartz-monzonite porphyry during the late Yanshanian period show close temporal–spatial relations with the mineralization, and have been dated as ca. 93–138 Ma by K–Ar method (Qin et al., 1999).

## 3. Deposit geology

The Jiawula deposit occurs 45 km to the northwest of Xin Barag Right Banner and 150 km to the southwest from Manzhouli City. The stratigraphy is dominated by Jurassic successions, composed of Middle Jurassic sandstone and conglomerate of the Nanping

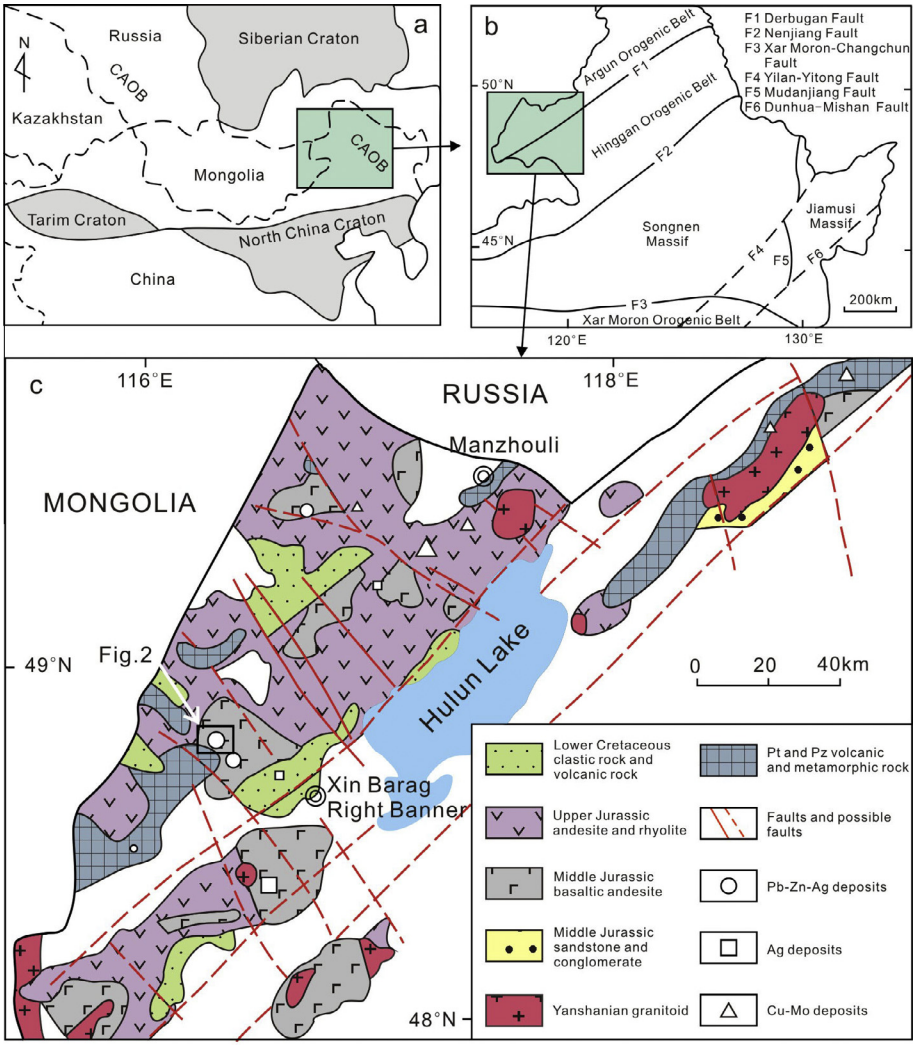


**Fig. 1.** Location and geological setting of the Manzhouli area at the northern extremity of the Da Hinggan Mountains (b modified from Ge et al. (2007); c modified from Wu et al. (2010)).