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Geology and origin of Ag–Pb–Zn deposits occurring in the Ulaan-Jiawula metallogenic province, northeast Asia

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ABSTRACT

Located at the conjunction area of China, Mongolia and Russia in NE Asia, the Ulaan-Jiawula (also referred as UJ) region, with an area of 400,000 km^2, is one of the most important Ag–Pb–Zn, U, Sn, W, Nb–Ta, and Au metallogenic provinces in Asia. At present, 2126 deposits and showings including 500 Ag–Pb–Zn deposits have been discovered, explored and mined since the late 1960s. These Ag–Pb–Zn occurrences can be subdivided into three types according to their geological setting, texture, alteration and mineral assemblages: (1) low sulfidation epithermal Ag–Pb–Zn deposits; (2) intermediate sulfidation epithermal Ag–Pb–Zn deposits; (3) mixed-type Ag–Pb–Zn deposit consisting of vein-like and tabular ore bodies. The Eren Tologoi and Tsagenbulagen deposits are representative of low-sulphidation type Ag–Pb–Zn mineralization in the UJ region, and are associated with intensive adularization and sericitization. Ore occurs as mineralized quartz veins, veinlet groups and altered-fracture zones within Mesozoic alkaline and high-K calc-alkaline volcanic rocks, Ore mineralogy includes native silver, electrum, pyrite, galena, sphalerite, arsenopyrite, pyrargyrite and chalcopyrite. The Tsav and Jiawula deposits are typical of intermediate sulfidation Ag–Pb–Zn mineralization. The $\delta^{34}S$ value of sulfide (pyrite and galena) separates from groups 1 and 2 varies from 1.5‰ to 3.5‰ and 2.0‰ to 4.5‰, respectively. The $\delta^{34}S$ values of the Mesozoic volcanic host rocks for groups 1 and 2 deposits also show the positive $\delta^{34}S$ values of 1.5–4.8‰, while the $\delta^{34}S$ value of pyrite separate from the pre-Jurassic schist range from −6‰ to −8‰ which are much lower than Mesozoic volcanic host rocks and their associated ore deposits. There is no difference between the $\delta^{34}S$ value of sulfide (pyrite and galena) separates from vein-like ore bodies of the group 3 deposits and their wall rocks, having $\delta^{34}S$ value of 1.0–5.0‰ and 1.2–4.5‰ which are similar to that of groups 1 and 2 deposits. For the Mesozoic monzogranite porphyry dykes and their associated tabular skarn ore bodies, the pyrite separates show $\delta^{34}S$ values of 2–5‰ and 1.8–3‰. All of these deposits show relatively radiogenic lead isotopic compositions compared to mantle or lower crust curves. Most lead isotope data of sulfides from the Ag–Pb–Zn ores plot between the Mesozoic volcano–hypabyssal rocks and pre-Jurassic metamorphic rocks. Monzogranite dykes at Ulaan and Noyon Tologoi have εNd (T) values ranging from 1.5 to 4.5 that are similar to most of the Mesozoic granite with positive εNd (T) values in the Great Hinggan Mountains-Mongolia orogenic belt. Data are interpreted as indicative of a mixing of ore-forming materials from mantle-derived alkaline and high-K calc-alkaline magma with these from pre-Jurassic metamorphic wall rocks. Isotopic age data, geological and geochemical evidence suggest that the ore fluids for the Ag–Pb–Zn deposits were generated during eruption or emplacement of the Mesozoic alkaline and high-K calc-alkaline magma. The Mesozoic magmas may provide heat, volatiles and metals for the group 1 and 2 deposits. Evolved metamorphic fluids produced by devolatilization, circulated the wall rocks, were also progressively involved in the magmatic hydrothermal system, and may have dominated the ore fluids during late stage ore-forming processes. Most of the Ag–Pb–Zn bodies that occur along the contact of the pre-Jurassic marble and Cretaceous monzogranite porphyry dykes at Ulaan and Noyon Tologoi are closely associated with skarn. The ore fluid of these group 3 deposit may have resulted from the mixing of Mesozoic magmatic water and evolved metamorphic fluids. Ore deposition in this instance would be the product of the interaction of the Mesozoic intrusions and pre-Jurassic carbonate rocks.

1. Introduction

The Ulaan-Jiawula (UJ) region, covers an area of 400,000 km^2, in the Central Asian Orogenic Belt, centered 1100 km north of Beijing

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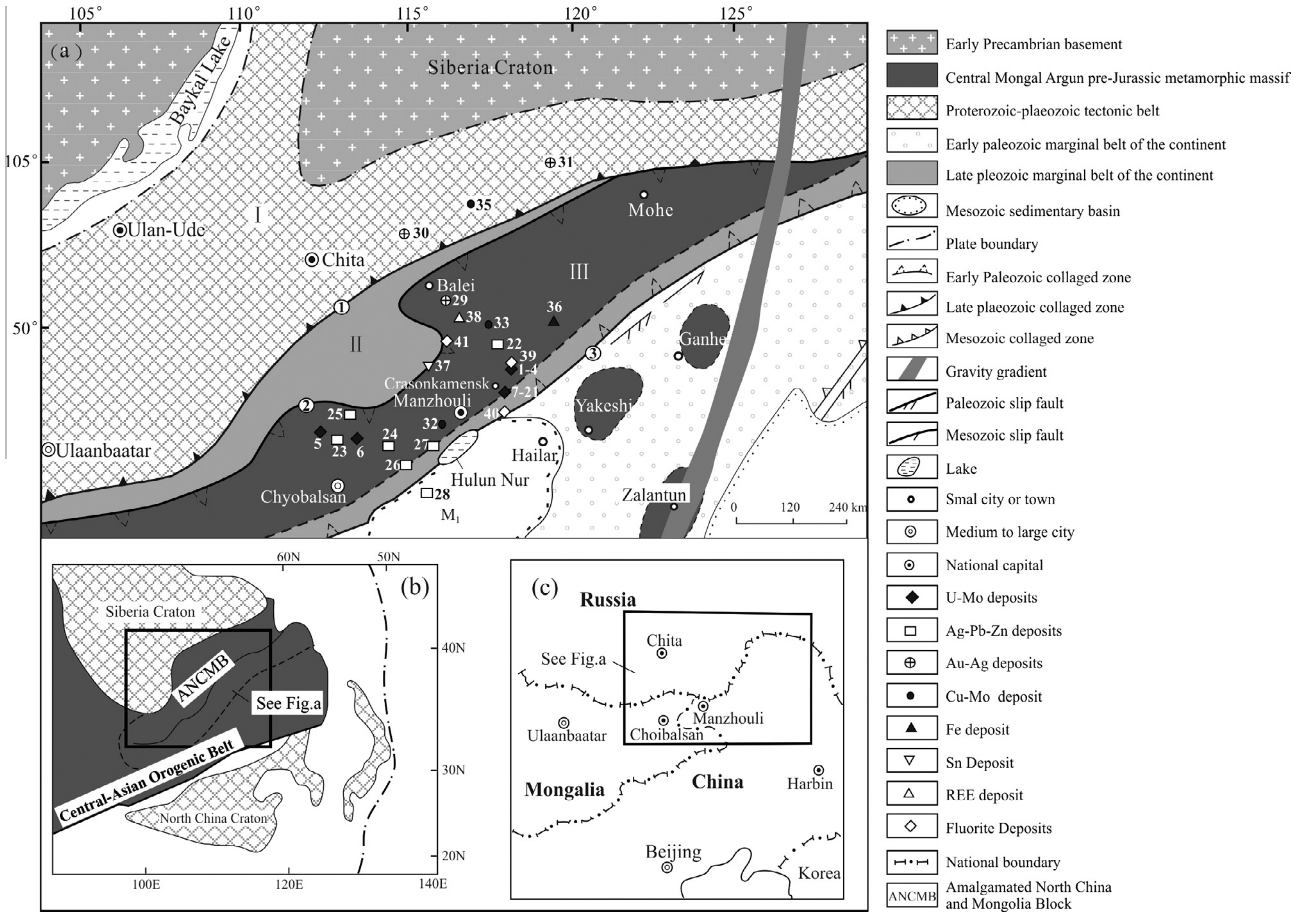

Fig. 1. Simplified geological map showing the location of major ore deposits in the Ulaan-Jiawula metallogenic province, eastern section of the CAOB. I – Siberian Craton; II – Group of terranes at the southern margin of Siberia plate; III – Mongolian-Okhotsk orogenic belt; IV – pre-Jurassic Central Mongolian-Argun (CMA) metamorphic massif; V – Hingan pre-Jurassic metamorphic massif; VI – Songliao–Silinhaote pre-Jurassic metamorphic massif; VII – Accretion zone at the northern margin of the North China Craton; VIII – North China Craton; M_1 – Hailar Basin; M_2 – Songliao Basin. Ore deposits (XL – Super Large Scale; L – Large scale): U–Mo deposits: 1 – Strelitsov (XL); 2 – Tulukuev (XL); 3 – Antei (XL); 4 – Argun (XL); 5 – Gul lwanbulak (XL); 6 – Dornot (L); 7 – Shilondukui (L); 8 – Oktiabrisk(L); 9 – Luchiste (L); 10 – Maltov (L); 11 – Malo Tulukuev (L); 12 – Rerlov (L); 13 – Ubilei (L); 14 – Piatilet (L); 15 – Vesheni (L); 16 – Novogod (L); 17, Krasnokamen (L); 18 – Ugozapad (L); 19 – Biezirechi (L); 20 – Dalini (L); 21 – East Shilondukui (L); Ag–Pb–Zn deposits: 22 – Noyon Tologoi (XL); 23 – Ulaan (L); 24 – Tsav (L); 25 – Muhar (L); 26 – Jiaula (L); 27 – Tsagenbulagen (L); 28 – Eren Tolgoi (L); 29 – Balei (XL); 30 – Dalasun (XL); 31 – Keliuchev (L); Cu–Mo deposit: 32 – Unugetushan (XL); 33 – Bugdain (L); 34 – Alin nur-(L); 35 – Rilejun (L); Fe deposit: 36 – Bielezov (L); Sn deposit: 37 – Sherl ovogor (L); REE deposit: 38 – Edkin (L); Fluorite deposit: 39 – Galsului (XL); 40 – Urtui (XL); 41 – Kalangui (L).

and 620 km east of Ulaan Baatart (Fig. 1). It hosts a wide range of metal deposits (U–Mo, Ag–Pb–Zn, Cu–Mo, Au, REE, W, Sn and Fe) and is the most important metallogenic province in Asia. Since the late 1960s, about 2126 deposits and showings including 500 Ag–Pb–Zn deposits have been discovered, explored and mined there (Dahlkamp, 2009; Hu et al., 1998; Pirajno et al., 2009; Yang, 2010; Yang et al., 2009; MITM, 2002; Zhu et al., 1996a, 1996b). 44 of these discoveries can be classified as super-large- and large-scale deposits (Hu et al., 1998). These include 21 U–Mo deposits, 9 Pb–Zn–Ag deposits, 4 Cu–Mo deposits, 2 Au deposits, 2 fluorite deposits, as well as single examples of Sn, W, Nb–Ta and REE deposits (Hu et al., 1998; MITM, 2002; Yang, 2010; Yang et al., 2009; Nie et al., 2007, 2010, 2014). The UJ metallogenic province is one of the most high density areas of large-scale deposits in the world, having one such deposit per 9000 km^2. Seventy percent of Mongolia's Ag–Pb–Zn deposits and 90% of the total Ag, Pb and Zn reserves are located in the UJ province. Moreover, the late Mesozoic volcanic–plutonic belt of UJ province also contains 95 Mongolia's U deposits, representing 98% of the country's total U endowment (Dahlkamp, 2009; Gantumur et al., 2005; Yang et al., 2009; Yang, 2010). Most of these Ag–Pb–Zn and U deposits (prospects) are hosted by the Late Jurassic to Early Cretaceous volcanic rocks. Two ore-related lithological associations were identified: (1) alkaline volcanic rocks, including trachyandesite, trachyte, potassic trachy-andesite (shoshonite), trachydacite, and latite; (2) high-K volcanic rocks: andesite, dacite, rhyolite, ignimbrite, tuff, oligophyric rhyolite lava, and vitroclastic felsic ash tuff. Most of the 500 Ag–Pb–Zn deposits in the UJ occur in the Mesozoic volcanic rocks, but there is an intimate spatial and temporal relationship between mineralization and hypabyssal intrusions of monzonite, monzodiorite, monzogranite, granite, and K-feldsparphric granite. Isotopic age data from the hypabyssal intrusions have two clusters: 170–150 Ma and 150–130 Ma. The representative Ag–Pb–Zn deposits reviewed in this paper are the Ulaan, Tasv, Bayndun and Muhar deposits in Mongolia; the Noyon Tologoi deposit in Russia; and the Jiawula, Tsagenbulagen and Eren Tolgoi deposits in China (Hu et al., 1998; Zhu et al., 1996a, 1996b; MITM, 2002; Dahlkamp, 2009; Dejidmaa et al., 2005).

These deposits are subdivided into three groups on the basis of host rock and mineral assemblage, namely (1) low sulfidation epithermal Ag–Pb–Zn deposits (e.g., Bayndun, Muhar Eren Tolgoi, Tsagenbulagen); (2) intermediate sulfidation epithermal Ag–Pb–Zn deposits (e.g., Tsav, Jiawula; and (3) mixed type Ag–Pb–Zn deposits consisting of tabular ore bodies and vein–stockwork ore lodes (e.g., Noyon Tologoi, Ulaan). The low-sulfidation style Ag–Pb–Zn deposits occur within Mesozoic volcanic sequences as