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Multiple sources and genesis of the Suoerkuduke Cu-Mo deposit during the Carboniferous, East Junggar: Insights from zircon U-Pb age and C-O-S-Pb isotopes

Xiujin Liu [a,*], Wei Liu [a], Wenjiao Xiao [b,c], Yong Wei [d]

[a] Key Laboratory of Mineral Resources, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[b] State Key Laboratory of Lithospheric evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[c] Xinjiang Research Center for Mineral Resources, Xinjiang Institute of Geography, Chinese Academy of Sciences, Xinjiang 830011, China
[d] Key Laboratory of Earth and Planetary Physics, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China

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ABSTRACT

The Suoerkuduke Cu-Mo ore bodies are closely associated with skarns, but this deposit shows distinct characteristics from typical contact metasomatic skarn deposits. No carbonate rocks and coeval magmatic activities were found in the oredistrict. Thus, there is no unidirectional zonation sequence from proximal to distal, but a bidirectional skarn zonation as follow: garnet skarn in the center, and epidote-garnet skarn, epidote skarn and diopside-hedenbergite skarn (with no symmetrical distribution) in outer parts. The sulfides are pyrite, chalcopyrite, molybdenite, sphalerite, galena and pyrrhotite, and no obvious sulfide zonation was observed.

The multiple sources of ore-forming fluids and ores imply a complicated and distinct metallogenic process of the Suoerkuduke deposit. The ore-forming fluids mainly consist of magmatic water, meteoric water and seawater. The coeval magmatic-hydrothermal activities took place in the nearby area of the Suoerkuduke oredistrict, but not within the oredistrict, indicating that magmatic water was most likely derived from a batholith at depth. This hidden batholith provided magmatic fluids, most of the sulfur and a portion of Cu metal for the Suoerkuduke deposit. The Mo metal was derived from the leaching of andesitic rocks and tuffaceous sandstone by meteoric water. The ascending magmatic fluids mixed with deeply circulated meteoric water and seawater, and then leached volcanic-pyroclastic rocks to enrich Ca, Fe and Cu metals. These fertile fluids subsequently metasomatised andesitic porphyry, pyroxene andesite and tuffaceous sandstone to form the skarn. The decrease in the temperature and fO_2 values facilitated the deposition of sulfides.

1. Introduction

The Suoerkuduke Cu-Mo deposit is hosted in Early Devonian volcanic-pyroclastic rocks and is temporally and spatially associated with skarn. Subvolcanic rock—pyroxene dioritic porphyry and felsic intrusive rocks—moyite and K-feldspar granite porphyry are exposed in the east and northeast parts of the oredistrict. Many types of porphyries, including dacite porphyry, granite porphyry and trachyte porphyry, are extensively distributed in the oredistrict. The Suoerkuduke deposit has been controversially defined as a porphyry Cu-Mo deposit (Liu et al., 1992), volcanic-subvolcanic hydrothermal stratabound deposit (Wei, 1992; Zhou et al., 1996), or skarn Cu-Mo deposit (Chen, 1993; Chen et al., 1995), because it is still uncertain whether the Cu-Mo mineralization is genetically related to volcanic and subvolcanic activity or felsic magmatic hydrothermal events. The ages of the Cu-Mo mineralization, pyroxene dioritic porphyry, dacite porphyry and trachyte porphyry were previously analyzed (Liu and Liu, 2013, 2014; Wan et al., 2014; Zhao, 2015; Zhao et al., 2015), and the Carboniferous Cu-Mo mineralization was not simultaneous with these porphyries. Therefore, it is necessary to clarify the temporal relationship between the Cu-Mo mineralization and moyite and granite porphyry, and further to determine which magmatic event may provide magmatic hydrothermal fluid and metallogenic materials for Cu-Mo mineralization. Meteoric water and seawater generally play important roles during Cu-Mo hydrothermal mineralization (Shelton, 1983; Meinert et al., 2003; Soloviev and Kryazhev, 2017). Cu-Mo is a common association and some Cu skarns contain zones of recoverable Mo (Meinert, 1992; Meinert et al., 2005; Li et al., 2008; Soloviev, 2015). However, Cu and Mo may have different sources, because Cu is chalcophile, while Mo is lithophile. It is important to make certain which types of fluids acquire and carry metallogenic materials from which sources to form skarn and sulfides.

* Corresponding author.
E-mail address: liuxiujin@mail.iggcas.ac.cn (X. Liu).

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Skarns in the Suoerkuduke deposit are pervasively distributed in the oredistrict, and they are closely associated with Cu-Mo ore bodies. The typical feature that defines skarn deposits is the occurrence of gangue skarn—a coarse-grained mixture of Ca-Mg-Fe-Al silicates formed by metasomatic processes and related to magmatic-hydrothermal activity associated with dioritic to granitic plutonism (Einaudi and Burt, 1982). The formation of skarns involves extensive metasomatic processes that result in complex calc-silicate mineral assemblages, exhibiting distinct zoning, from endoskarns (within the margins of the causative intrusion), progressively to proximal and distal exoskarns (andradite garnet, diopside, actinolite, tremolite, wollastonite, calcite, epidote, talc and serpentine) and silicified marble outward from the intrusion (Meinert, 1992; Meinert et al., 2005; Pirajno, 2009). Stratiform skarns have been studied by several researchers (Stanton, 1987; Ashley and Plimer, 1989; Chiaradia, 2003; Liu et al., 2012), and contact metasomatic skarns have also been universally discussed (Ciobanu and Cook, 2004; Durand et al., 2006; Yücel-Öztürk et al., 2008; Mollai et al., 2009; Golmohammadi et al., 2015). However, stratiform skarns at Suoerkuduke display many unique characteristics compared to previous examples and typical contact metasomatic skarns, such as lacking carbonate and calcareous rocks, and displaying bilateral symmetric zonation. These distinct features may imply a different formation process of the Suoerkuduke deposit contrast to a typical skarn deposit.

In this study, we first present the zircon U-Pb ages of moyite and granite porphyry to confirm whether the magmatic hydrothermal event could be responsible for the Cu-Mo mineralization at Suoerkuduke. Geological features of skarn and ore deposit are presented to comprehensively discuss the genesis of the Suoerkuduke Cu-Mo mineralization as well as its contrast with typical skarn deposits. The C-O isotopes of carbonate and S-Pb isotopes of sulfides are analyzed to dissect the multiple origins of fluids and metals, and further discuss the formation process of the Suoerkuduke Cu-Mo deposit.

2. Regional geology and ore geology

2.1. Regional geology

East Junggar is an important part of northern Xinjiang (Fig. 1a) and is located on the southern margin of the western part of the Central Asia Orogenic Belt, which is abundant in ore deposits reviewed by

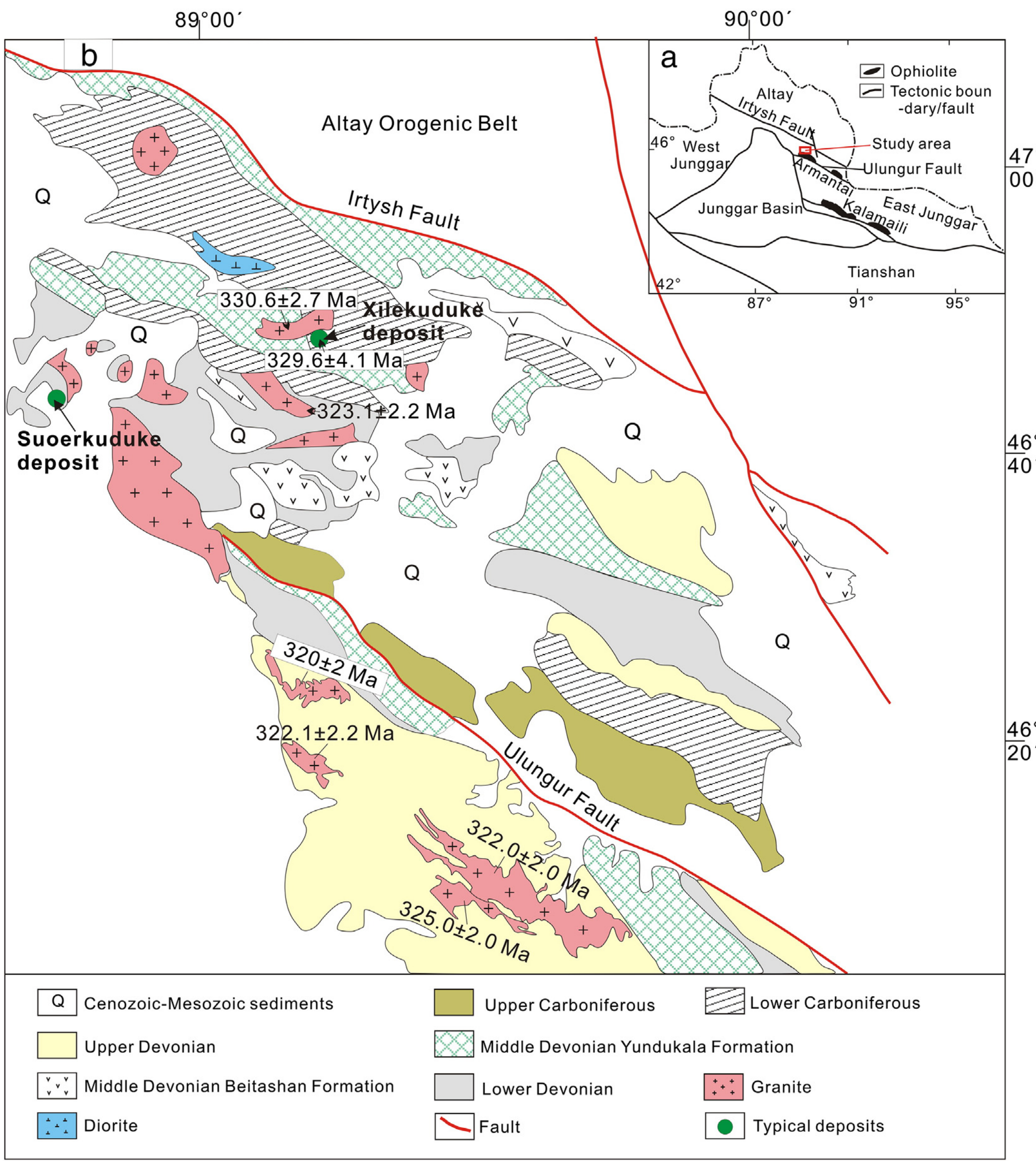

Fig. 1. a) Location of the study area in the Junggar Terrain; b) Geological map of the north of East Junggar showing the distribution of Neopaleozoic Cu-Mo deposits, intrusions and volcanic-sedimentary rocks. 1-Cenozoic–Mesozoic; 2-Upper Carboniferous; 3-Lower Carboniferous; 4-Upper Devonian; 5-Middle Devonian Yundukala Formation; 6-Middle Devonian Beitashan Formation; 7-Lower Devonian Tuoranggekuduke Formation; 8-Granite; 9-Diorite; 10-Fault; 11-Cu-Mo deposit.

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