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内蒙古霍各乞Cu-Pb-Zn矿床的剪切带与岩性控矿特征及意义

作者	单位	E-mail
钟日晨	北京科技大学土木与环境工程学院, 北京 100083;北京大学造山带与地壳演化教育部重点实验室, 北京 100871	
李文博	北京大学造山带与地壳演化教育部重点实验室, 北京 100871	liwenbo@pku.edu.cn
陈衍景	北京大学造山带与地壳演化教育部重点实验室, 北京 100871	
皮桥辉	桂林理工大学地球科学学院, 桂林 541004	

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摘要：

内蒙古霍各乞大型Cu-Pb-Zn矿床地处内蒙西部狼山地区，为狼山-渣尔泰山成矿带的典型矿床。前人依据该矿裂谷沉积赋矿、岩性控矿、具有层状矿体等宏观特征判断其为裂谷环境下形成的热水沉积矿床，但也有部分学者提出其为受构造控制的后生热液矿床。本次研究以岩矿相学观察为基础，结合热力学模拟，提出该矿为受剪切带控制的变质热液矿床。矿区内赋矿围岩普遍经历角闪岩相区域变质作用及韧性剪切变形。宏观上，矿体与矿区内剪切带产状协调。硫化物总体沿围岩糜棱岩片理产出，但局部切割围岩糜棱岩组构，含矿微裂隙具有脆韧性剪切变形特征，可见硫化物交代围岩峰期变质矿物。热液脉石矿物组合及矿物温压计均表明成矿期具有低绿片岩相的温压条件。上述特征表明Cu-Pb-Zn矿化受剪切带控制，发生于剪切变形晚期，围岩退变质抬升阶段。热力学模拟显示当含矿流体流经由碳质千枚岩、石英二云母片岩和富铁夹层构成的岩性柱子，碳质千枚岩层位发生Pb-Zn矿化，而石英二云母片岩层位发生Cu矿化，富铁层位形成富矿体，这与霍各乞的地质事实相一致，矿相学观察也表明围岩岩性对成矿具有控制作用，因此后生热液流体与围岩的水岩反应导致了霍各乞矿床的层控、岩矿特征。通过上述研究建立起的剪切带控矿的成矿模式既符合该矿的显微观察结果，又可以解释该矿层状矿体、岩性控矿等宏观特征。

英文摘要：

The large Huogeqi Cu-Pb-Zn deposit in Inner Mongolia is a typical case of the Langshan metallogenic belt. The genesis of this deposit is controversial. Most researchers regard it as a hydrothermal exhalative deposit, based on its macroscopic geological characteristics, such as the ore-hosting rift sequences and the stratiform and stratabound orebodies. However, other researchers argue that the Huogeqi is a structure-controlled epigenetic hydrothermal deposit. A detailed microscopic observation is the most effective approach to discriminate between metamorphosed and metamorphogenic deposits in metamorphic terranes, but no systematic petrographic and mineragraphic studies have been carried out before this study. In this study, a shear zone controlled genetic model was proposed based on detailed microscopic petrographic and mineragraphic observations, combined with thermodynamic modeling. Host rocks of the deposit were amphibolite facies metamorphosed, with peak temperature of 600~650℃. A shear zone was developed in the mining filed, and most of the host rocks were strongly mylonitized. The orebodies are generally concordant with the shear zone in the mining area, and sulfides were precipitated generally alone mylonite foliations of the host rocks. Although sulfides and hydrothermal gangue minerals are generally parallel to mylonite foliations, they locally cut cross mylonite fabrics of host rocks. Peak metamorphic minerals of the host rocks (e.g., garnet) were locally replaced by hydrothermal sulfides and gangue minerals. Sulfides precipitated with hydrothermal minerals such tremolite, chlorite, epidote, biotite, Fe-talc, spessartine, hydrobiotite, muscovite and quartz, which are resemble the mineral assemblage of lower greenschist facies metamorphic rock. Mineral thermobarometers and microthermometeric analysis of fluid inclusions yield a lower greenschist facies ore-forming *P-T* condition as well. Ore hosting microfractures show signatures of brittle-ductile shear deformation, indicating that the mineralization took place at the crustal depth of brittle-ductile transition zone, which is characterized by greenschist facies pressure-temperature condition as well. Taken that the host rocks were amphibolite facies metamorphosed, the ore-forming process took place during uplift and retrograde metamorphism of the host rocks. All these observations indicate a shear zone-controlled hydrothermal mineralization that took place postdating peak metamorphism of the host rocks. Since the mineralization process postdates peak metamorphism and ductile deformation of the host rocks, it should be significantly later than sedimentation and diagenesis of the host rocks, i.e., an epigenetic mineralization. In the Huogeqi, Pb-Zn orebodies are mainly hosted by carbonaceous shale, whereas Cu orebodies are hosted by quartzite and mica schist layers of the host rock. This stratabound nature of this deposit has been regarded as one of the most important evidence supporting the exhalative genetic model. A flow-through thermodynamic modeling was carried out to account for the stratabound nature of the deposit. The modeling results show that the sulfide-saturated primary ore-fluids will be strongly reduced when flowing through the carbonic shales, resulting in a dramatic elevation in Cu solubility but a mild increase in Pb and Zn solubility. Due to the great elevation in Cu solubility, the fluid will maintain undersaturated in Cu during the subsequent fluid cooling, a

nd forming Cu-poor Pb-Zn ores in the carbonic shale layers of the host rock. During progressive fluid cooling, Cu finally turned to be oversaturated in the fluid. Massive Cu was precipitated from the ore-fluid accompanying minor Pb and Zn, forming Cu-rich orebodies in the quartzite mica schist layers. This is consistent well the stratabound nature of the Huogeqi deposit. When flowing through Fe-rich layers, reduced sulfur in the ore-fluids were strongly interacted with Fe in the host rocks, leading to sulfidation of the Fe-rich host rocks. Host rock sulfidation will consume a large amount of reduced sulfur in the fluid, which is the major ligand of Cu, Pb, and Zn transport. Consequently massive Cu, Pb and Zn will precipitate from the ore-fluid as a result of host rock sulfidation, forming high-grade ores in Fe-rich host rocks. Sulfidation of Fe-rich host rocks is observed at the contact between Fe-rich rocks and syntectonic hydrothermal veins. In host rocks composed of interlayered quartzite and Fe-rich pyroxene, sulfides were mainly precipitated in the Fe-rich layers. In a single hydrothermal veinlet, high-temperature hydrothermal minerals such as tremolite are commonly replaced by low-temperature mineral assemblages such as chlorite-epidote, and both the high-temperature and low-temperature mineral assemblages are accompanied by sulfides. This indicates that a dramatic fluid cooling event occurred during sulfide precipitation, and fluid cooling is an important mechanism of mineralization. All these observations are consistent well with the modeling result, indicating that the stratabound and stratiform nature of the deposit is a result of fluid-rock interaction between the epigenetic ore-fluid and the host rocks.

关键词：铜铅锌 矿相学 热力学模拟 剪切带 造山型矿床 内蒙古

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