Metallogenic dynamics and model of cobalt deposition in the eastern Kunlun Orogenic Belt, Qinghai Province

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1 Introduction

Recently discovered cobalt is an important mineral species in the eastern Kunlun Orogenic Belt and has shown favorable prospecting prospects, high tenor and large scale reserves. To date, three cobalt deposits have been discovered: that is, Kendekeke and its periphery cobalt-bismuth-gold deposit, Tuolugou cobalt-gold deposit and Dulenggou copper-cobalt deposit. Cobalt has the characteristics of being heat-resistant, wear-resistant, high strength and strong magnetism. Furthermore, its alloy and alloy steel are important additives which are indispensable to aviation, electrical appliances and the chemical industry. There are associated cobalt deposit and independent cobalt deposit in this orogenic belt. What are the ore-controlling characteristics and how about their ore-forming metallogenic dynamic mechanism and geology of mineral deposit? The dissertation briefly discusses these scientific problems.

2 Regional geology of the eastern Kunlun Orogenic Belt

The eastern Kunlun Orogenic Belt represents the western part of China's central orogen, and is located in the southern margin of Qaidam massif. The belt has undergone polycyclic complex orogenic processes, polycyclic ocean-continent transition and complex intercontinental evolution after the collision. As a result, typical structure-magma-sedimentation occurred. From north to south, the eastern Kunlun orogenic belt can be divided into the Kunbei back-arc basin, Kunzhong basement uplift and granitic belt and Kunnan composite belt. The predominant strata include the Precambrian, Ordovician, Carboniferous-Permian and Triassic. E-W fracture zones have formed in the eastern Kunlun orogenic belt since the Paleozoic due the influence of three regional faults. Extensive magmatism developed and different epoch rock assemblages demonstrate the plate subduction-collision and evolution of a polycyclic ocean.

Metamorphism drove element redistribution and enrichment in the eastern Kunlun orogenic belt. For the significant contribution of metamorphism to mineral deposit is that it can supply metamorphic fluids, remobilize the mineral elements and extract the mineral elements from source beds.

Regional gravity and aeromagnetic anomaly present the N-W orientation in the Western part, E-W orientation in Middle part and N-E orientation in Eastern part. Gravity anomaly reflects E-W and N-W orientation gradient belt and mineral resources of non-ferrous metal have close relationship with the N-W orientation gravity and aeromagnetic anomaly. Along the gravity gradient belt and periphery of the aeromagnetic anomaly, some commercial nonferrous metal deposits have been discovered. Ore bodies are commonly hosted in anomaly intersections. Eastern Kunlun mineralized belt is located in an active fractured zone, lithospheric thinning and has a coincident relationship with strong earthquake centers. Mineral deposits formed along the low velocity zone and the transitional belt between the high velocity zone and low velocity zone.

Volcanic rocks of Eastern Kunlun orogenic belt can be divided into four series: pre-Xingkai, Caledonian, Variscan and Indosinian-Yanshanian. Pre-Xinkai volcanic rocks are composed of basaltic lava of Wanbaogou group. Chemical components of volcanic rocks wholly belonged to subalkalic series. Characteristics of geochemistry and sedimentation formation indicated that the forming environment was oceanic volcanic island. Caledonian volcanic rocks include Nachitai group and Tanjianshan group. Furthermore, volcanic rocks of Tanjianshan group are bimodal volcanic rocks composed of basic basalts and intermediate-acidic basalts. Geochemistry shows the Tanjianshan group developed in a back-arc basin tectonic

environment. Nachitai group contributed some limestone and siliceous rocks that formed in deep water. Variscan volcanic rocks are composed of the Maoniushan, Dagangou, Halaguole and Haoteluowa group. Calcalkalic volcanic rocks of early Carboniferous Halaguole group are rocks developed in an island arc or active continental margin. Halaguole group of Kunnan composite belt develop tholeiitic basalt series and Calcalkalic series characterized by magmatic arc showing its formation have genetic relation with the northward subduction of Bayan Har ocean.

Exhalative sedimentation formations are developed extensively in Eastern Kunlun orogenic belt. Because of the influence of the different metallogenic geological-structural setting, some special submarine hydrothermal exhalation sedimentation formations were formed. For example, Kendekeke ore district located in Qimantage aulacogen developed siliceous rocks-bearing Sedex formation. However, Tuolugou ore district located extensional oceanic setting developed siliceous albitite-bearing volcanic clastic debris sedimentation formation. Dulenggou copper deposit is formed in a subduction back-arc of Bayan Har ocean and developed Calcalkalic series magmatic arc.

3 Geodynamic evolution of the eastern Kunlun Orogenic Belt

Based on observations made by previous researchers and our own investigations, the geological history of the orogen can been divided into three stages, i.e. pre-Caledonian, Caledonian and Indochinese-Himalayan.

Pre-Caledonian evolution includes formation of Precambrain platform, breakup and convergence of Proterozoic paleocontinent. Wanbaogou oceanic bassalts, which are important to understand the tectonic evolution, were formed in late Proterozoic. The ocean plate of the Proto-Tethys began to be consumed by northward subduction to Qaidam massif along the location of the present Kunzhong falut in early Paleozoic, and the structural framework of Kunbei and Kunnan formed. With the development of the subduction, a trench formed in the sourthern margin of Qaidam massif. Active continent margin was formed between the Kunzhong fault and Kunbei fault, but a back arc basin formed in Kunbei belt. Bimodal volcanic rocks were distributed extensively. By that time, a trench-arc-basin system was developed in the southern edge of Qaidam massif.Nachitai group, which is composed of volcanic clastic rocks and carbonatite formation was formed in the basalt plateau after formation of the Wanbaogou oceanic basalt and before collision with Qaidam massif. In early middle Silurian, siliceous albitite formed in extensional tectonic setting of Wanbaogou oceanic basalt plateau. In late Caledonian, Wanbaogou plateau basalts were collaged to the Qaidam massif.

According to Luo et al. (1990), the late Paleozoic volcanic rocks formed in an Andean-type continental magmatic arc. The oceanic crust was directly subducted downward to the continent without island arc formation

The Hercynian batholiths, are the most widely developed intrusives in the orogenic while early Indochinese granites are mostly stock-shaped and mainly distributed in Kunnan belt. Based on petrochemical data, it is recognized that the granites of this stage belong to subduction and syncollisional types. Since the late Indochinese stage, intensive crustal-mantle reaction occurred, which lead to the formation of a series of widely distributed mafic-ultramafic intrusives. The tectonic regime transformed from compressional orogeny to extensional liosphere thinning, which coincided with the beginning of the breaking up of the supercontinent Pangea. The tectonic regime transformation controlled the formation of mantle-derived, mantle-crustal hybrid magmatic activities and a large number of hydrothermal ore deposits in late Indochinese.

4 Characteristics and model of cobalt deposition in the eastern Kunlun Orogenic Belt

Kendekeke Co, Bi and Au deposit: This deposit developed in the early Paleozoic back-arc basin of the Kunbei fracture zone. With the northward subduction of seamounts, the back-arc basin and submarine hydrothermal exhalation sedimentation ore-bearing formation formed. Submarine hydrothermal exhalation sedimentation formed siliceous rocks together with pyrites, pyrrhotites, gel pyrites and other Co, Bi, Au and Cu multiple ore-forming elements. Because of the short life of the active basin, thermal influence was relatively minor; the hydrothermal sedimentation provided important ore-forming materials for the later mineralization. Hercynian orogenic activities enriched the mineral elements again. Large scale mineralization developed in Mesozoic era and is the predominant mineralization stage for the Kendekeke deposit. Indosinian-Yanshanian magma brought strong thermodynamics condition and hydrothermal replacement. Tuolugou Co deposit: Bayan Har Ocean was located in the southern part of Eastern Kunlun orogenic belt entered the oceanic subduction phase after the Paleozoic extension. Metallic elements were accumulated by hydrothermal activities caused by seeping of seawater and formations bearing Co and Au. Modified mineralizations and deformation of fold and shear developed during Yanshanian-Himalayan thrusting. There were extensive structural deformation and replacement and no large scale magmatic intrusions in Kunnan belt similar to the paleozoic Kunzhong belt. Primary stratifications were replaced by penetrative foliations. Mineralized siliceous albitite were deformed and reoriented and characteristics of veinlike deposits were generated. Later phase structures developed intensively and cut the original mineralization belt and formed diverse uplift and denudation.

An oceanic basalt plateau was produced by a mantle plume in the Pro-Tethys ocean in the Precambrian and hydrothermal activities developed extensively. With the rift extending downward to the deep crust or upper mantle, basic vocanics were deposited widely. Large scale hydrothermal sedimentation and submarine exhalation were active for a long time. Co, Cu and others metalic elements from Archean formations were remobilised into the sea basin and accumulated and deposited in the hydrothermal vents.

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