Hydrogen and oxygen isotopes characteristics in various types gold deposits in Jiaodong peninsula, China

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***Abstract*—The Jiaodong Peninsula is the largest gold district in China. There are three types of gold deposits which are recognized as quartz vein, fracture-altered and interlayer slippage type in Jiaodong. The paper studied hydrogen and oxygen stable isotopes from three different types gold deposits in Jiaodong. The results showed that the source of ore-forming fluids in the three types gold deposits were both from the mixture of magmatic water and meteoric water. And the ratio of the meteoric water in ore-forming fluids, from small to big, was fracture-altered, quartz vein and interlayer slippage type, respectively. The mapping of hydrogen and oxygen studies showed that the Jiaojia and Denggezhuang deposits were with the largest value of $\delta^{18}O$ and the Qixia deposit was with the smallest value of $\delta^{18}O$.**

***Index Terms*—Hydrogen and oxygen isotopes; gold deposits; types; Jiaodong**

I. INTRODUCTION

The Jiaodong Peninsula is the premier gold district in China with total measured gold reserves exceeding 1000t, and current annual production of over 30tonnes. There are conflicting views regarding the sources of ore-forming fluids in the Jiaodong gold province. the fact that most of the gold orebodies are hosted in 160 to 150 Ma Linglong-type biotite granite or 130 to 126 Ma Guojialing-type granodiorite has prompted a group of researchers to suggest that the ore-forming fluids were dominantly derived from granitic magma, which increasingly mixed with meteoric water during the late stages of hydrothermal activity[1,2]. Others, on the basis of stable isotope systematics and initial ratios of Sr isotopes, suggested that the major component of the ore-forming fluids was meteoric water, or that the meteoric water mixed with small amounts of magmatic fluid[3,4]. Owing to the close spatial relationship between the orebodies and Cretaceous lamprophyre dykes, together with some evidence of mantle-derived components, other researchers argued that deep fluids or mantle-derived fluids were responsible for the gold deposits in the Jiaodong Peninsula [5,6].

One method to constrain the nature of ore-forming fluids is to study stable isotopes, such as those of hydrogen, oxygen, sulfur and nitrogen [7,8]. In the present work, we present hydrogen and oxygen isotopic data obtained from 6 quartz vein type, 3 frature-altered type and 2 interlayer slippage type gold deposits. Based on the results of this study, an attempt is made to determine the source of ore-forming fluids, discuss the differences of three types gold deposits and make a map of distribution of hydrogen and oxygen isotopes in Jiaodong peninsula.

II. REGIONAL GEOLOGICAL SETTING

The Jiaodong peninsula is located along the southe-eastern margin of the North China carton and at the western margin of the Pacific Plate. It is bounded to the west by the NNE-trending Tanlu Fault zone that extends for thousands of km fom the Yangtze River north to Far East Russia. The peninsula is divided into two-Hurassic tectonic units: the Jiaobei terrane in the north and Sulu Terrane in the south. These terrane are separated by the Wulian-Yantai suture (Figure 1). The Sulu Terrane is at the eastern end of the Qinling-Dabie-Ulu diamond and coesite-bearing ultra-high pressure metamorphic belt. The Jiaobei Terrane consists of the Jiaobei uplift in the north and the jiaolai basin in the south.

Based on historical production rates, this area is the largest repository of gold (>35 Moz Au) in China. Most of the gold deposits are distributed between the Tanlu fault zone and the Wulian-Qingdao-Yantai fault. The latter is considered to be the boundary between the North China Craton and the Sulu ultrahigh-pressure (UHP) orogenic belt. The northwestern Jiaodong Peninsula is composed primarily of Precambrian metamorphic sequences, Mesozoic volcanic rocks and granitoids, and minor Mesozoic sedimentary cover rocks. The Precambrian sequences primarily comprise the Late Archean amphibolite to granulite facies of the Jiaodong Group, and the Proterozoic Fenzishan and Penglai Group are composed of low-grade metasedimentary rocks. The Jiaodong Group, which was dated at 2665 Ma using the U-Pb zircon method, consists primarily of mafic to felsic volcanic and sedimentary rocks and has been identified as an Archean greenstone belt. The Mesozoic granitoids that intrude the high-grade Jiaodong Group can be subdivided into the three following groups according to their compositional and textural characteristics and their field relationships: (1) a granite-granodiorite group that is primarily composed of biotite granites, granodiorites and monzonites; (2) a porphyritic granodiorite group that consists of porphyritic, hornblende-bearing granodiorites, monzogranites and granites; and (3) a peralkaline granitoid group that consists primarily of monzonites and syenites. Most of the large gold mines in the Jiaodong Peninsula are hosted in the widely distributed metaluminous to slightly peraluminous granitoids of the first two groups. These include the Linglong and Jiaojia gold deposits that are hosted in the 160 Ma to 156 Ma old Linglong medium-grained biotite granite and the 130 Ma to 126 Ma old Guojialing porphyritic granodiorite.

The gold deposits can be classified into: 1) quartz vein type, as exemplified by the Linglong gold deposit; 2) altered-fracture type, as in the Jiaojia deposit, and interlayer slippage type as shown by the Dujiaya and Pengjiakuang deposits [9].

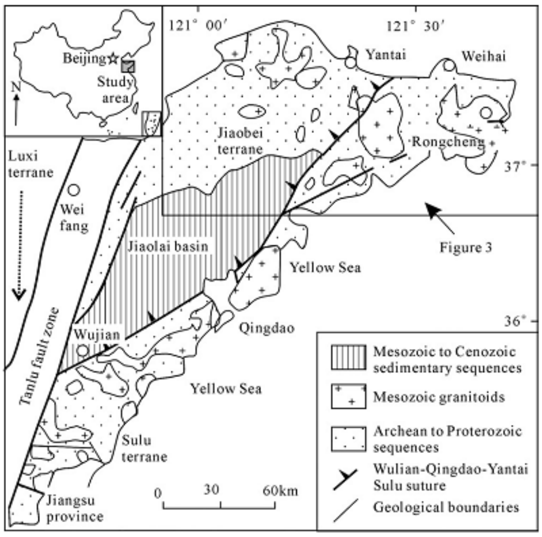

Figure 1 Simplified geological map of the Jiaodong Peninsula (according to [10])

From west to east, the large gold deposits of the Jiaodong Peninsula are mainly distributed in the Zhaoyuan-Laizhou (or Zhao-Ye), the Qixia-Yantai, and the Rushan-Mouping gold belts. Two types of gold deposits have been identified; the Linglong type of Au-bearing quartz lode gold and the Jiaojia type of hydrothermal alteration accompanied by disseminated pyrite in this area have a consistent spatial-temporal association with the Late Jurassic-Early Cretaceous magmatism (approximately 130 Ma to 110 Ma) in eastern China, which has been determined to be related to lithospheric thinning. Detailed information about the geological setting and the genesis of the gold lode deposits has been described in previous studies.

III. Methods

Only fresh samples of alteration rock and ore-body from the underground mine at the level from +140 m to -230 m were selected from the underground working are and were prepared for ore microscopy and petrology as polished thin sections and polished blocks. The individual minerals were extracted from the various ore veins and were lightly crushed to a grain size of approximately 40 to 60 mesh using a carefully pre-cleaned agate mortar and pestle. They were washed and then handpicked to a purity of more than 99% under a binocular microscope.

Pure quartz separates were prepared for hydrogen and oxygen isotope analysis. The O-isotopic compositions of quartz were analyzed following the BrF5 method. The δ18O values were determined on a Finigan MAT 252 ratio mass spectrometer. The δD values of water were analyzed using the Zn reduction method. H2 and CH4 from the fluid inclusions were first converted to H2O by passing through a CuO furnace at a temperature of 600℃. Next, all of the H2O was combined and converted to H2 by reacting with Zn in a vacuum line. The δD values were measured on the same mass spectrometer. The D/H ratios are expressed in the δD value in ‰ relative to V-SMOW. The reproducibilities of both δ18O and δD were ±1‰. The oxygen isotopic compositions of the hydrothermal waters in equilibrium with quartz were calculated using an extrapolation of the fractionation formula from Taylor (1974). The calculations of the fractionation factors were made using the mean value of the homogenization temperatures of fluid inclusions plus pressure-corrected temperatures.

The 11 hydrogen and oxygen isotopes data is collected from the programme studied and previous literatures. The D/H ratios are expressed inδD value in ‰ relative to V^{-SMOW}. Relproducibilities of both $\delta^{18}O$ and δD are ±1‰.TheδD values were analyzed directly from fluid inclusions in auriferous vein quartz. The $\delta^{18}OH_2O$ values were calculated from $\delta^{18}O$ of quartz using the formula: $1000In\alpha quartz\text{-}water=3.38\times10^6/T^2-3.4$ [11].

IV. Results and Discussion

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A. Characteristics of hydrogen and oxygen isotopes

The hydrogen and oxygen isotopes results are listed in Figure 2. The δD values obtained from fluid inclusions in quartz can accurately reflect the δD values of the hydrothermal fluid. The δD values of water are in distinguishable and have a narrow range of -95.7 to -51.8 per mil in quartz vein type gold deposits. Using the formula reported by clayton et al(1972), the δ18OH2O values calculated from δ18O values of quartz range from -8 to 8.06 per mil in quartz vein type gold deposits. The δD values of water and δ18OH2O values of fracture-altered type and interlayer slippage type are range from -95.8 to -32.99 and 8.8 to 13.97 per mil,-97.9 to -79 and 0.59 to 4.03 per mil. As shown in Figure 2, the fluids of the quartz veins and fracture-type ores may represent magmatic water mixed with some meteoric water. Compared to the quartz vein type ore, the fluids of the fracture-altered type are dominated by magmatic fluids and less admixed meteoric water. The fluids of the interlayer slippage type ores is slightly different from the others in that it's mixed with large amounts of meteoric water. Mixing of fluids was favored in the interlayer slippage type mineralisation, because this style was developed in a relatively open system along NE-trending fractures and detachment faults of the Jiaodong basin.

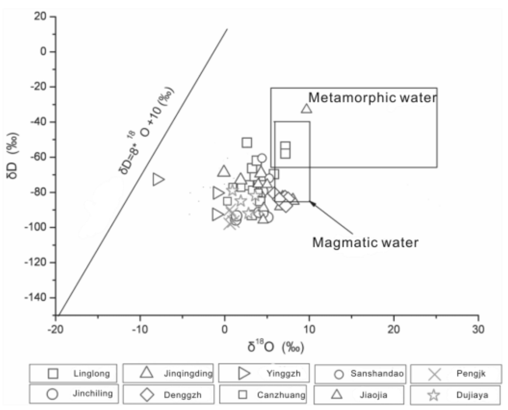

Figure 2 The hydrogen and oxygen isotopes characteristics of different type gold deposits in Jiaodong.

B. Mapping of the hydrogen and oxygen isotopes

We carried on the $\delta^{18}OH_2O$ values mapping in Jiaodong and obtained a distribution map (see Figure 3). In the Figure 3, the results show that the $\delta^{18}OH_2O$ values exist two higher areas: 1) Sanshandao and Jiaojia area, 2) Denggezhuang and Rushan area. These two areas represent the ore-forming fluids are mixed with more magmatic water. There is a lower area with low $\delta^{18}OH_2O$ values in Qixia area. This area represent the ore-forming fluids are mixed with more meteoric water.

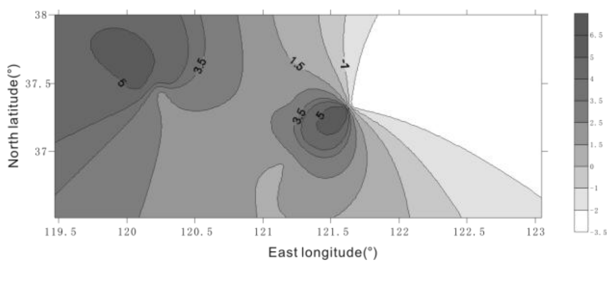

Figure 3 Distribution of $\delta^{18}OH_2O$ values mapping in Jiaodong

V. Conclusions

1) The ore-forming fluids of all these types gold deposits were mainly from the mixture of magmatic water and meteoric water. And the meteoric water in ore-forming fluids from small to big is fracture-altered, quartz vein and interlayer slippage type, respectively.

2) The results show that the δ18OH2O values exist two higher areas (one is Sanshandao and Jiaojia and the other is Denggezhuang and Rushan area) ,which represent the ore-forming fluids are mixed with more magmatic water. There is a lower area with low δ18OH2O values in Qixia area, which represents the ore-forming fluids are mixed with more meteoric water.

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