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Gold mineralizing efficiency during hydrothermal alteration of the Mesozoic granitoids in the northwest Jiaodong Peninsula: Contrasting conditions between the Guojialing and Linglong plutons

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ABSTRACT

Mesozoic granitoids were extensively altered by hydrothermal fluids in the northwest Jiaodong Peninsula, and gold precipitated from the fluids developing prevalent mineralization in this district. The 160–158 Ma Linglong granite and 130–120 Ma Guojialing granodiorite are the major Mesozoic granitoids in this district, both of which are hydrothermally altered and intimately associated with gold mineralization. Although numerous studies were carried out by previous researchers, mainly focusing on tectonics, lithology, mineralogy, geochronology, and fluid geochemistry, knowledge about hydrothermal alteration processes of these granitoids and their gold mineralization efficiency (i.e. which one is more effective to precipitate the gold from its parent solution) is far beyond clear illumination. Geochemical simulation software GEM-Selektor (based on the Gibbs energy minimization algorithm) was applied in this study, which aims to test the gold mineralization efficiency of these two granitoids during the hydrothermal alteration processes. Simulation results indicate that solutions in equilibrium with the Linglong granite are capable of hosting more sulfur than that with the Guojialing granodiorite, since the latter contains more Fe. However, the solutions with these two granitoids display similar gold solubility. “Bulk cooling” simulation results show that the gold mineralization pattern is similar between the Linglong and Guojialing case; “Rock titration” simulation results reveal that the Guojialing granodiorite is prone to precipitate gold more strongly than the Linglong granite, as gold-bearing solutions (or ore-forming fluids) flowing-through at high temperature, equivalent to a deeper level, implying that if the gold mineralization is developed at depth, the Guojialing rock will precipitate more gold. If the gold-bearing solution flow-through the wall rocks relatively fast, and gold mineralization fails to take place, then the Guojialing granodiorite is probably unfavorable for subsequent gold enrichment of the ore-forming fluid. The Linglong granite will precipitate the gold more efficiently from its parent solution at low temperature or at a shallower level, and this is consistent with previous mining prospecting results. Therefore, we suggest that the Guojialing granodiorite should be treated as the main target during future deep prospecting project.

1. Introduction

Hydrothermal alteration is extensively developed in gold deposits in the Jiaodong district, and the mineralization type is called “Jiaojia-type” (e.g. Li et al., 2015; Wen et al., 2015). The wall-rocks altered by ore-forming fluid are mostly Mesozoic granitoids, especially the Linglong granite and Guojialing granodiorite, and gold deposits are frequently hosted by these rocks. Thus, it is widely believed that the hydrothermal alteration processes of these granites are related to gold mineralization (Fan et al., 2003; Chen et al., 2005; Song et al., 2012; Li et al., 2013; Li et al., 2015; Song et al., 2015a; Fan et al., 2016; Jiang et al., 2016; Yang et al., 2016).

The mineral assemblages developed by hydrothermal alteration are generally uniform, mainly consisting of K-feldspar + quartz + sericite + sulfides ± carbonate ± chlorite ± epidote ± magnetite, in which sulfides consist mostly of pyrite with minor pyrrhotite, chalcopyrite, sphalerite, and galena (Li et al., 2015). Besides, hydrothermal alteration stages are also similar for these deposits,

Abbreviations: Bi, biotite; Cal, calcite; Kfs, K-feldspar; Mt, magnetite; Pl, plagioclase; Py, pyrite; Qz, quartz; Sd, siderite; Ser, sericite.

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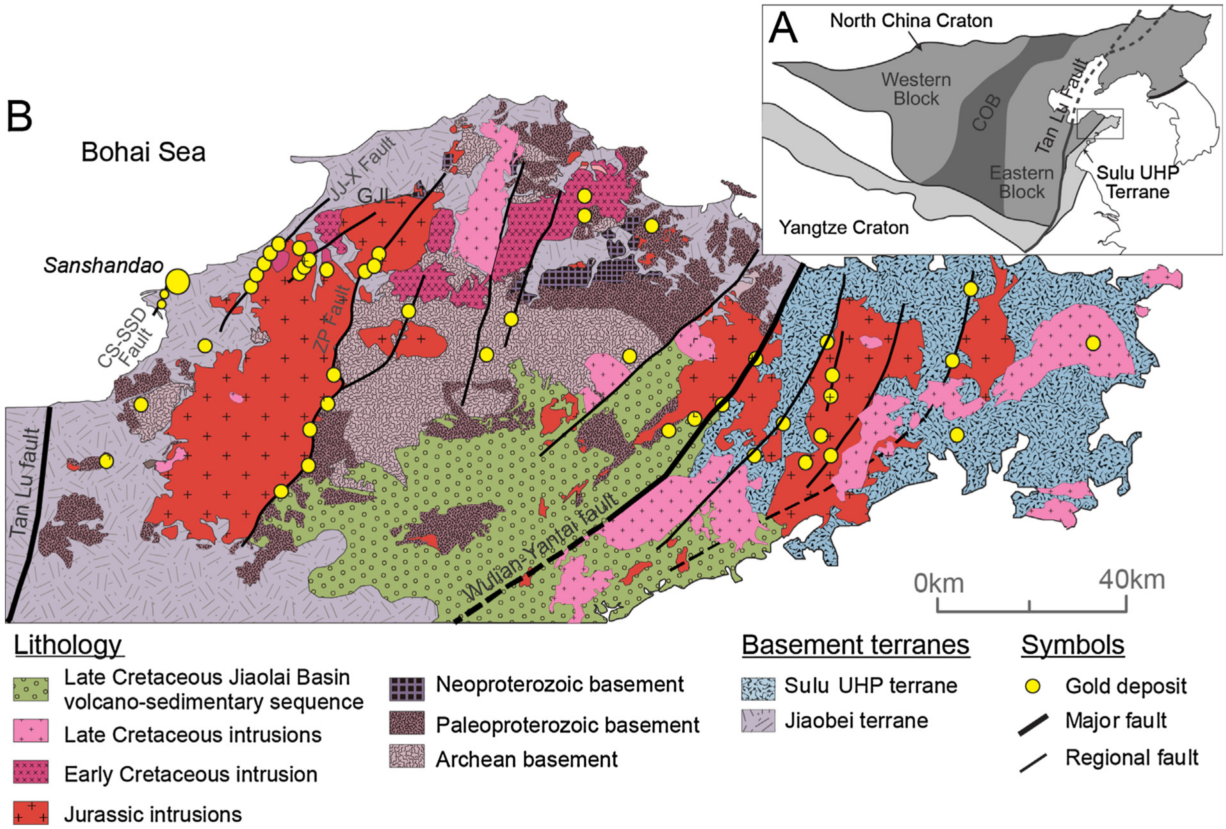

Fig 1. (A) Regional map of the North China Craton, and (B) geological map of the Jiaodong Peninsula (Modified from Fan et al., 2003).

including early potassic alteration + silicification + sericitization-sulfidation (pyritization) + latest carbonatization. These phenomena indicate that the fluids inducing the hydrothermal alterations associated with gold mineralization are consistent for these gold deposits. Although the characteristics of the hydrothermal alteration of these granitic wall rocks are almost identical, the extent of gold mineralization scales varies in different granitoids. For instance, in the Sanshandao gold deposit, the largest one in China with an Au reserve >2000 t (Song et al., 2015b), gold is mainly hosted by the Linglong granite at a shallow level, whereas it changes to be hosted in the Guojialing granodiorite in the deeper sections (Fan et al., 2003, 2016; Jiang et al., 2011; Song et al., 2012; Li et al., 2013). The Jiaojia gold deposit, another large one in northwestern Jiaodong Peninsula, is predominantly hosted by the Linglong granite (Jiang, 2011), but as revealed by a new exploration effort, gold mineralization is also developed in the Guojialing granodiorite located at depth (Prospecting reports). As the exploration goes deeper, the Guojialing granodiorite is increasingly the focus of mining companies. In summary, the gold mineralization capacity of the Linglong and Guojialing intrusions is distinguishable, or, in other words, their gold mineralization efficiency is different.

In this work, we attempt to illuminate the details of the gold mineralization during hydrothermal alteration of the wallrocks of the Linglong and Guojialing intrusions and to interpret the differences of the gold mineralization efficiency between them, providing information for further prospecting projects in this area.

2. Geologic settings

The Jiaodong Peninsula in the eastern part of the North China Craton (NCC) constitutes China's largest gold province and one the major gold field in Asia (Goldfarb and Santosh, 2014) (Fig. 1). The gold mineralization formed at a short time scale around 125–120 Ma (Yang et al., 2000; Li et al., 2003; Li et al., 2006; Jiang et al., 2009; Goldfarb and Santosh, 2014; Song et al., 2015a; Fan et al., 2016), and has been universally classified into two types: (1) the Linglong-type, occurring as extensional massive gold-quartz-pyrite veins, is typically represented by the Linglong, Jiuqu, Jingqingding and Denggezhuang deposit; and (2) the Jiaojia-type, originally named from the Jiaojia deposit, occurs as disseminated veinlets and disseminated mineralization in wallrocks along fractures, including Sanshandao and Dongfeng deposits, except for the Jiaojia deposit (Fan et al., 2003, 2016; Song et al., 2012; Li et al., 2013; Li et al., 2015; Song et al., 2015a; Wen et al., 2015).

The origin of the gold deposits in the Jiaodong Peninsula is being debated, although numerous scientific studies have been carried out (e.g. Yang et al., 2000; Li et al., 2003; Zhai et al., 2004a; Li et al., 2006; Jiang et al., 2009; Zhai and Santosh, 2011; Goldfarb and Santosh, 2014; Song et al., 2015a; Fan et al., 2016; Jiang et al., 2016; Yang et al., 2016). There are two different viewpoints of the origin, orogenic and anorogenic. The former is based on structural settings and ore fluid geochemistry, mainly supported by Goldfarb et al. (2007); the latter is supported by other researchers who compared the tectonic setting and mineralization characteristics of Jiaodong deposits with those of typical orogenic gold deposits over the world, and pointed out that the gold deposits in Jiaodong Peninsula are distinct to the typical orogenic deposits, which are better to be named "Jiaodong-type" gold deposits (Zhai et al., 2004b), recently it was changed to "decratonic-type" gold deposits (Zhu et al., 2015). Most importantly, though, the characteristics of hydrothermal alteration and gold mineralization have been defined clearly, despite the debated origin.

Hydrothermal alteration process always commences from potassic alteration, through silicification and sericitization, to sulfidation, and ends at the carbonatization stage (Fig. 2). Potassic

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