The Yangshan gold belt is a major gold resource with six main gold deposits. The identified recoverable resource is reported to be more than 300 tonnes Au, making it one of the largest gold belts in China besides the well-known Jiaodong gold province and Sanjiang Tethys area (Deng et al., 2006; Yan et al. 2010; Yang et al., 2011). Although researchers have done some research work (e.g. Chen et al. 2004; Li et al., 2012), the insufficient petrological evidence of mineral paragenesis and the traditional experimental methods hinder the significance of many previous studies. The laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) has been proven to be a powerful tool for defining separate pyrite growth zones and hydrothermal mineralization events (e.g. Large et al., 2009; Thomas et al., 2011). However, little research has been conducted for gold deposits in China. In this study, detailed petrological evidence is provided for the mineral paragenesis of the gold deposits. The EPMA and LA-ICP-MS analyses are conducted to discriminate the different sulfide generations by their element patterns, which can be used as a proxy for defining the hydrothermal events (e.g. Thomas et al., 2011) and it may be useful for further exploration through the identification of gold-rich sulfide minerals and for classifying the deposit genetic type.

The gold belt is situated in the Shaanxi-Gansu-Sichuan “Golden Triangle” region of China, which is the broad junction between the North China Craton, Yangtze Craton and Songpan-Ganzi fold belt (Zhang et al. 1996). The Bikou Group and the Devonian Sanhekou Group, which were metamorphosed up to the lower greenschist facies, are the major strata in the study area. Intrusions in the gold belt include granite, aplite, and porphyry dikes. The granitic rocks were sheared into lenses along the Anchanghe-Guanyinba fault system. Most pre-ore granitic rocks are ca. 210 Ma and were subsequently altered and mineralized to variable degrees (Qi et al. 2005). The gold belt is structurally located on the Wexian arcuate structure, which is part of the Mian-Lue suture zone. The secondary E-W-trending Anchanghe-Guanyinba fault system and Getiaowan-Caopingliang anticline control the orebodies of the gold belt.

Detailed paragenetic studies have recognized five stages of sulfide mineral precipitation in the deposits of the belt. Syngenetic/diagenetic pyrite (Py0) has a frambooidal or colloform texture and is disseminated in the metasedimentary host rocks. Early hydrothermal pyrite (Py1) in quartz veins is disseminated in metasedimentary rocks and dikes, and also occurs as semi-massive pyrite aggregates or bedding-parallel pyrite bands in phyllite. The main ore stage pyrite (Py2), commonly overgrows Py0 and Py1 and is typically associated with main ore stage arsenopyrite (Apy2). Late ore stage pyrite (Py3), arsenopyrite (Apy3), and stibnite occur in brittle quartz±calcite veins or are disseminated in country rocks. Post-ore stage pyrite (Py4) occurs in quartz±calcite veins that cut all earlier-formed mineralization.

The EPMA and LA-ICP-MS studies of the major and trace element compositions of sulfides show that the Py0 has relatively high values of As, Au, Bi, Co, Cu, Mn, Ni, Pb, Sb, and Zn. This syngenetic/diagenetic pyrite is interpreted to have been the source for the gold resources in the Yangshan gold belt, when it was metamorphosed at higher temperature conditions existing below presently exposed crustal levels in the belt. Compared with hydrothermal pyrite, Py0 contains more Pb and Zn in solid solution and retains characteristic sedimentary Co/Ni ratios. Early hydrothermal Py1 has relatively high contents of As, Au, Bi, and Sb, and we suggest that these high concentrations of ore-related elements in the hydrothermal fluids were released into solution via metamorphism of country rocks at depth. Main ore stage Py2 has highest concentrations of As and Au, showing the intense fluid-
rock interaction during the most important gold-forming event. Arsenic in main ore stage Py$_2$ occurs in metastable Fe(As,S)$_2$ solid solution and the arsenian pyrite was rapidly precipitated. A coupled substitution mechanism could explain the correlation between As and Au. Late ore stage Py$_3$ contains high contents of Sb, which is consistent with the widespread stibnite. Comparing the main and late ore stage arsenopyrite, the former has higher As levels, whereas the latter has higher concentrations of S, Fe, and Sb, which is consistent with main and late ore stage pyrite. The late hydrothermal event likely occurred at slightly lower temperatures and/or shallower depths, due to ongoing uplift of the orogenic belt (Yan et al. 2010; Li et al., 2014).

In the Yangshan gold belt, Au is mostly present as “invisible gold” within pyrite and arsenopyrite, although some native gold also occurs in the late ore stage. All the pyrite (Py$_0$–Py$_3$) analyses plot below the solubility limit line, showing that most Au is present in solid solution (Au$^{1+}$) in arsenian pyrite (Reich et al. 2005), which is further evidenced by the HRTEM images of Py$_2$ and Apy$_2$, showing there is no obvious dislocation or deformation in the mineral crystal structure and no gold minerals are observed.

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**References**


