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Isotopic characteristics of gold deposits in the Yangshan Gold Belt, West Qinling, central China: Implications for fluid and metal sources and ore genesis

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ABSTRACT

The six main Triassic gold deposits of the Yangshan gold belt are hosted by Devonian metasedimentary rocks and Triassic granitic dikes. It has been suggested by previous workers that they are best classified as either Carlin-like or orogenic gold deposit types. Sulfide minerals spatially associated with disseminated and quartz vein-hosted gold mineralization at Yangshan were deposited in five stages that include syn-metamorphic, early ore, main ore, late ore, and post-ore stages. Based on the relationships defined by ore-mineral assemblages and paragenesis, H, O, C, S, Pb, and Sr isotopic data were obtained from sulfides, quartz, and ore host rocks. The $\delta^{18}O$ values of quartz from gold-bearing veins range from 15.9‰ to 21.5‰, and the calculated $\delta^{18}O_{H2O}$ values of ore-forming fluids vary from 6.4‰ to 11.8‰, which are consistent with those from typical orogenic gold deposits. The δD_{H2O} values of fluid-inclusions extracted from the quartz vary from −82‰ to −56‰, which are in accord with the δD_{H2O} values of most orogenic gold deposits. Interpretation of the $\delta^{13}C_{CO2}$ values (−4‰ to −2.5‰) in fluid inclusion, shows that marine carbonate is the dominant source for the carbon in the ore-forming fluids, with a minor contribution from magmatic sources. The $\delta^{34}S$ values of hydrothermal pyrite, arsenopyrite, and stibnite range from −6.6‰ to 3‰, which suggests sulfur is derived from a deep source. The Pb isotope values for hydrothermal sulfides from both the granitic dike-hosted ores and phyllite-hosted ores overlap the fields for their respective wall rocks, which suggests the source of lead is either the local host rocks, or ore-related fluids that may have pervasively penetrated the host rocks. The age-corrected $(^{87}Sr/^{86}Sr)_i$ values of pyrite are 0.70627 to 0.71304, and values for arsenopyrite are 0.71258 to 0.71294, showing that the strontium in the ore fluid could have been derived from the granitic dikes and the regionally extensive Mesoproterozoic to Neoproterozoic Bikou Group. The concordance of $\delta^{34}S$, Pb and $(^{87}Sr/^{86}Sr)_i$ values between those for hydrothermal sulfides and country rocks suggests that these crustal rocks contributed the gold that was subsequently concentrated in the ore deposits. The syn-metamorphic stage and early ore stage fluids were likely derived from the country rocks during prograde metamorphism at depth. The oxygen isotope compositions indicate relatively widespread interaction of such fluids with $\delta^{18}O$-rich country rocks during the main ore stage. Compared with most orogenic gold deposits and Carlin-type gold deposits, the gold deposits in the Yangshan gold belt exhibit isotopic characteristics that are most like those of orogenic gold deposits.

1. Introduction

Although many of the ore forming characteristics of orogenic gold deposits are reasonably well understood, debate continues on their genesis largely because it is difficult to reliably identify the source of the gold (Goldfarb et al., 2005, 2014; Phillips and Powell, 2009; Large et al., 2011; Tomkins, 2013). Isotopic data (e.g. C, H, O and S) from orogenic gold deposits can indicate a variety of possible sources for ore fluids and metals (Goldfarb and Groves, 2015). Most isotopic tracers are not diagnostic of a fluid or metal source because of the isotopic exchange between ore fluids and wall rocks, uncertainties in degree of isotopic fractionation during ore mineral precipitation, and possible post-ore resetting of isotopic settings (McCuaig and Kerrich, 1998; Ridley and Diamond, 2000; Groves et al., 2003). Isotopic research based on spatial and temporal variation between mineral grains may shed light on the metal sources and ore-forming fluid evolution (Chen et al., 2012; Deng et al., 2011, 2014a).

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Table 1
Characteristics of the main orebodies in the Yangshan gold belt.

Gold deposit	Orebody assemblage number	Gold reserves (kg)	Gold grade (g/t) (average)	Thickness of orebody (m) (average)	Inclination of orebody	Wall rock	Mineralization pattern
Anba	305	94,390	5.35	4.84	150–175° ∠ 45–70° 320–340° ∠ 45–60° 150–175° ∠ 45–70° 320–340° ∠ 45–60°	Altered phyllite, granite	Disseminated
	360	68,038	4.40	4.71	160–170° ∠ 48–68° 160–170° ∠ 48–68°	Altered phyllite, granite	Disseminated
	311	104,936	4.69	3.35	150–175° ∠ 55–65° 150–175° ∠ 55–65°	Altered phyllite, granite, quartz veins (locally)	Veinlet, disseminated
Yangshan	2	11,527	9.62	2.78	20–40° ∠ 20–36° 20–40° ∠ 20–36°	Altered granite, cataclastic limestone	Blocky, veinlet, disseminated
	13	6486	3.13	7.02	185–205° ∠ 42–60° 185–205° ∠ 42–60°	Altered phyllite, granite, limestone	Blocky, veinlet, disseminated
Getiaowan	402	6923	4.63	3.24	330–20° ∠ 30–45° 330–20° ∠ 30–45°	Altered phyllite, granite	Disseminated
	403	811	4.71	4.53	165–205° ∠ 53–70° 165–205° ∠ 53–70°	Altered phyllite, granite	Disseminated
	404	866	2.12	2.19	330–10° ∠ 20–45° 330–10° ∠ 20–45°	Altered phyllite, granite	Disseminated
Nishan	501	/	2.22	3.18	160–200° ∠ 45–75° 160–200° ∠ 45–75°	Altered granite	Disseminated
	504	/	5.80	1.09	340–10° ∠ 60–85° 340–10° ∠ 60–85°	Altered phyllite, granite	Disseminated
	506	/	4.15	3.07	5–45° ∠ 45–70° 5–45° ∠ 45–70°	Cataclastic phyllite, granite	Veinlet, disseminated
	508	/	1.58	4.63	160–190° ∠ 40–60° 160–190° ∠ 40–60°	Altered phyllite, granite	Disseminated
	509	/	1.67	2.37	170–10° ∠ 45–65° 170–10° ∠ 45–65°	Altered phyllite, granite	Disseminated
Zhangjiashan	101	/	0.03–1.18	1.40	330–350° ∠ 50° 330–350° ∠ 50°	Altered granite, silicified phyllite	Disseminated
	102	/	2.27, 0.52	7.76–28.44	355° ∠ 40°	Altered granite, cataclastic phyllite with limestone	Veinlet, disseminated
Gaoloushan	201	/	0.5–12.8	0.5–2	185–210° ∠ 30–55°	Altered phyllite	Disseminated
	207	/	4.06	3.56	200–260° ∠ 35°	Altered phyllite	Disseminated
	209	/	2.46	2.47	200–230° ∠ 25–45°	Altered phyllite	Disseminated