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Carbon isotope studies of auriferous quartz carbonate veins from two orogenic gold deposits from the Neoarchean Chitradurga schist belt, Dharwar craton, India: Evidence for mantle/magmatic source of auriferous fluid

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ABSTRACT

Carbon and oxygen isotopic compositions of carbonates from auriferous quartz carbonate veins (QCVs) of two orogenic gold deposits – Ajjanahalli and Guddadarangavvana Halli (G.R. Halli) – from the Neoarchean Chitradurga schist belt of the Dharwar craton, southern India are examined to understand the origin of the mineralizing fluids. The average carbonate carbon ($\delta^{13}C_{pdb}$) and oxygen ($\delta^{18}O_{smow}$) isotope compositions of QCVs of Ajjanahalli are −5.5 ± 1.3‰ and 14.1 ± 2.7‰, respectively. The same ratios for the QCVs of G.R. Halli are −6.2 ± 1.9‰ and 14.1 ± 0.5‰. The corresponding average fluid $\delta^{13}C$ and $\delta^{18}O$ compositions are −5.81 ± 1.14‰, 13.78 ± 5.1‰ for Ajjanahalli and −4.64 ± 0.7‰, −6.50 ± 0.6‰ for G.R. Halli. The $\delta^{13}C_{pdb}$ of syn-sedimentary carbonates of BIF of Ajjanahalli (−1.8 ± 0.1‰), carbonated metabasalts of Ajjanahalli (−1.4‰) and G.R. Halli (−1.3‰) fall in the compositional range of marine carbonates (0 ± 2‰). As dissolution/decarbonation reactions during metamorphism of pre-existing carbonate/carbonated rocks produce CO_2 with $\delta^{13}C$ values similar to or more enriched than parent rock, the carbonate or fluid $\delta^{13}C$ ratios of the QCVs (which fall in the compositional range of mantle/magmatic derived CO_2 or carbonates) obtained in this work cannot be the result of metamorphism. It is proposed that gold mineralizing fluids were derived from juvenile magmatic melts and were channeled through crustal scale shear zones to give rise to the gold deposits.

1. Introduction

Orogenic gold deposits are known from Middle Archaean to Tertiary metamorphic belts (Goldfarb et al., 2005). They are all structurally controlled and occur in late syntectonic crustal scale shear zones (Kerrich and Cassiday, 1994). Orogenic gold deposits are characterized by remarkably similar compositions of the ore forming fluids (low salinity, $H_2O–CO_2 \pm CH_4 \pm NaCl$ circulated at 1.5 ± 0.5 kbars and 350 ± 50 °C (Groves et al., 2003)). Several hypotheses have been proposed for the origin of ore fluids: (i) metamorphic devolatilization reactions of hydrous and carbonate minerals during prograde metamorphism (Kerrich and Fyfe, 1981), (ii) fluids evolved from devolatilization of felsic intrusions (Burrows et al., 1986), (iii) CO_2-rich fluid flux during mantle degassing (Groves et al., 1988), (iv) fluid from gold-rich lamprophyre magma (Rock et al., 1989), and (v) deep meteoric water circulation (Nesbitt, 1988). Of these, the first two models have been widely proposed as possible mechanisms for the origin of fluids that led to the formation of many orogenic gold deposits (Ridley and Diamond, 2000). Gold occurs in quartz carbonate veins (QCVs) in the orogenic gold deposits. C and O isotopes of carbonate minerals and silicates of QCVs have been studied extensively in many other regions of the world to constrain the source of auriferous fluids (Table 1). Such studies are very limited on gold deposits in India. Santosh (1992) based on C and O isotopic composition of fluid inclusions inferred mantle source for fluids that gave rise to world renowned gold deposits in the Kolar greenstone belt. Santosh et al. (1995) attributed similar origin of fluids for the Wynaad Gold deposits located in granulites. Pandalai et al. (2003) based on C and O isotopic composition of fluid inclusions also suggested subcrustal origin of fluids for the Hutti gold deposits. Kolb et al. (2004) based on silicate oxygen isotopic study of Ajjanahalli deposit found that $\delta^{18}O_{H_2O}$ is suggestive of magmatic/mantle origin.

To be able to unequivocally choose between metamorphic devolatilization and magmatic/mantle origin of the mineralizing fluids, it may be pertinent to carry out isotope studies not only on carbonate and silicate minerals in the QCVs, but also on these mineral phases in surrounding rocks in auriferous belts, because, the latter can potentially produce CO_2 rich fluids during metamorphism. Studies so far, as summarized in Table 1 have not taken into

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Table 1
$\delta^{13}C$ and $\delta^{18}O$ for carbonates and silicate minerals from orogenic gold deposits of the world.

Deposit and area	$\delta^{13}C_{carbonate}$ (‰) (range/average)	$\delta^{18}O_{carbonate}$ (‰)	$\delta^{18}O_{silicate}$ (‰)	Inferred fluid source
[a]Hunt mine, Mt. Charlotte, Victory and Golden Mile, Yilgarn, Australia	−6.6 to −4.4, −7.9 to −8.8, −8.7 to −4.6, −4.1 to −1.5	~8 to 14		Juvenile CO_2 flux from mantle
[b]Kalgoorlie, Australia and 15 deposits, Timmins, Canada	−3.4 ± 0.4, −3.1 ± 1.3, −3.0 ± 1.5.			Magmatic
[c]Leverton, Yilgarn gold province, Australia	−2.3 to −8.3			Mantle/lower crust
[d]Hollinger, McIntyre, Dome, Buffalo-Ankerite, Macassa, Lamque, Hasaga, Lake Superior, Canada	−3.4 ± 0.4, −3.2 ± 0.3, −4.5 ± 1.7, −2.8 ± 0.6, −3.2 ± 0.3, −5.4 ± 0.9, −5.3 ± 0.5.	10.1 ± 1.4–12.8 ± 0.7		Metamorphic devolatilization
[e]Val-d-'Or, Abitibi, Canada	−1.9 to −8.0	6.9–12.5		-do-
[f]Kalahari Goldridge, South Africa.	−3.3 to −8.0	9.4–13.3	12.2–19.2	Mantle(?)
[g]Ulundi, Barberton belt, South Africa	−3.7 to −4.9	12.8–13.2		Mantle
[h] Deposits of Barberton belt, South Africa	−2.2 to −4.5	11–13	12–13	External
[i]Rio das Velahs, Brazil	−6.3 ± 1.3 to −7.0 ± 0.8 (mafic host); −6.9 to −7.4 (BIF host)	12.3 ± 0.5–13.2 ± 0.4; 15.8–17.4		
[j]Sams Creek, New Zeeland (NZ)	−4.1 to −5.5 (granite hosted)	12.6–19.8	12–16.8	Mantle (?)
[k]10 gold deposits of Jiadong Peninsula, China (largest granitoid hosted orogenic gold deposit)	−3.4 to −6.4; −3.0 to −5.6; −3.4 to −5.4; −4.0 to −6.4; −0.4 to −2.0; −0.1 to −4.8; −0.9 to −3.5	10.1–12.1; 8.4–12.4; 11.6–13.1; 8.4–13.5; 4.2–12.5 l; 6.9–11.6		Mantle(major) + Crust (minor)
[l]Daping gold deposit, China + lower crust (minor)	−3.0 to −6.5 (FI)			Mantle(major)
[m]Jiadong gold Province, China (granite hosted)	−4.5 to −6.3	8.3–8.7		Mantle
[n]Mayum, Tibet, China			13.7–16.3	Deeper level metamorphism ± magmatic
[o]Jaipigou, China	−4.2 to −5.0		5–12	Magmatic
[p]Ajjanahalli, Dharwar, India			13.6–14.4	Metamorphic devolatilization
[q]Kolar, Dharwar, India	−5.9 to −6.8 (FI)			Mantle
[r]Wynad, India	−9.1 to −9.2 (carbonate) −4.1 to −5.9(FI)	7.6–7.8	9.2–10.9	Mantle
[s]Biriman, West Africa			15.2 ± 0.310.9 ± 0.3 ($\delta^{18}O_{H_2O}$)	Magmatic
[t] Samgwang, Korea			−5.9 to 10.9 ($\delta^{18}O_{H_2O}$)	Magmatic
[u] Meuguma Terrane, Canada (Ovens and Duffin Deposits)			15.2 ± 0.9, 15.7 ± 0.6	Metamorphic
[v]Sovetskoye, Russia	−4.9 to 5.2 (FI)			Syntectonic magmatism
[w]Slate Belt & Pingfengshan, Taiwan	−2.14 to −6.86	5.92–20.21		Metamorphic
[x]Jinshan, South China	−5.0 to −4.2	4.4–8.0		Mantle/Metamorphic

[a] Groves et al. (1988).
[b] Burrows et al. (1986).
[c] Kerrich (1989).
[d] Salier et al. (2005).
[e] Beaudoin and Pitre (2005).
[f] Hammond et al. (2007).
[g] Schrümann et al. (2000).
[h] De Ronde et al. (1992).
[i] Lobato et al. (2001).
[j] Faure and Brathwaite (2006).
[k] Mao et al. (2008).
[l] Sun et al. (2009).
[m] Qiu et al. (2002).
[n] Jiang et al. (2009).
[o] Miao et al. (2005).
[p] Kolb et al. (2004).
[q] Santosh (1992).
[r] Santosh et al. (1995).
[s] Hammond et al. (2011).
[t] Yoo et al. (2010).
[u] Kontak et al. (2011).
[v] Tomilenko et al. (2010).
[w] Craw et al. (2010).
[x] Li et al. (2010).

account the isotopic composition of carbonate/silicate minerals in the surrounding rocks.

2. Regional geological setting

Regional geological map of the Dharwar craton of southern Indian shield is shown in Fig. 1. The craton is comprised of Neoarchean schist belts, referred to as greenstone belts in other shield areas of the world. The schist belts are separated from each other by 3.4 Ga to 2.55 Ga Meso- to Neoarchean TTG gneisses known as the Peninsular Gneiss and 2.52 Ga late Neoarchean granitoids (the Closepet Granite and its equivalents). Archean lithostratigraphic sequence in the schist belts of the Dharwar craton is summarized in Table 2. The Dharwar Supergroup consists of volcanic and sedimentary rocks belonging to 2.91 Ga to 2.76 Ga Bababudan Group and 2.72 to