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Geology and geochemistry of the shear-hosted Julie gold deposit, NW Ghana

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ABSTRACT

The Leo Man Craton in West Africa is host to numerous economic gold deposits. If some regions, such as the SW of Ghana, are well known for world-class mineralizations and have been extensively studied, gold occurrences elsewhere in the craton have been discovered only in the last half a century or so, and very little is known about them. The Julie gold deposit, located in the Paleoproterozoic Birimian terrane of NW Ghana, is one such case. This deposit is hosted in a series of granitoid intrusives of TTG composition, and consists of a network of deformed, boudinaged quartz lodes (A-type veins) contained within an early D_{J1} E–W trending shear zone with dextral characteristics. A conjugate set of veins (C-type) perpendicular to the A-type veins contains low grade mineralization. The main ore zone defines a lenticular corridor about 20–50 m in width and about 3.5 km along strike, trending E–W and dipping between 30 and 60°N. The corridor is strongly altered, by an assemblage of sericite + quartz + ankerite + calcite + tourmaline + pyrite. This is surrounded by a second alteration assemblage, consisting of albite + sericite + calcite + chlorite + pyrite + rutile, which marks a lateral alteration that fades into the unaltered rock. Mass balance calculations show that during alteration overall mass was conserved and elemental transfer is generally consistent with sulfidation, sericitization and carbonatization of the host TTG.

Gold is closely associated with pyrite, which occurs as disseminated grains in the veins and in the host rock, within the mineralized corridor. SEM imagery and LA-ICP-MS analyses of pyrites indicate that in A-type veins gold is associated with bismuth, tellurium, lead and silver, while in C-type veins it is mostly associated with silver. Pyrites in A-type veins contain gold as inclusions and as free gold on its edges and fractures, while pyrites from C-type veins contains mostly free gold. Primary and pseudosecondary fluid inclusions from both type veins indicate circulation in the system of an aqueous-carbonic fluid of low to moderate salinity, which entered the immiscibility PT region of the H_2O–CO_2–NaCl system, at about 220 °C and <1 kbar.

1. Introduction

The Birimian terrains in southern Ghana (particularly the Ashanti and Sefwi belts) have been the focus of commercial gold exploration and exploitation since the early 1900s. Due to the commercial implications of gold, extensive geological studies have been completed on these belts by many workers including Junner (1932, 1935, 1940), Kesse (1985), Milési et al. (1989, 1992), Eisenlohr and Hirdes (1992), Blenkinsop et al. (1994), Mücke and Dzigbodi-Adjimah (1994), Hünken et al. (1994), Oberthür et al. (1994, 1996, 1997, 1998), Mumin and Fleet (1995), Hammond and Tabata (1997), Klemd et al. (1996), Barritt and Kuma (1998), Yao and Robb (2000), Perrouty et al. (2012). Gold mineralization in southern Ghana is associated with a wide range of metamorphosed rocks. According to Leube et al. (1990) and Taylor et al. (1992), the gold mineralization usually occurs in chemical facies, defined by cherts,

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manganese and carbon-rich sediments, Fe–Ca–Mg carbonates where sulfide mineral disseminations intermittently developed at the transition between volcanic belts and metasedimentary basins. The gold deposits west of the Ashanti Mine on the Ashanti belt are hosted by granodiorite and tonalite that intrude the metasediments (Allibone et al., 2002). Allibone et al. (2004) showed that most of the gold mineralization in southern Ghana occurs within and adjacent to northwest trending thrust faults that define the regional-scale structural architecture. Gold-ore forming fluids in southern Ghana are usually CO_2 dominated as indicated by the presence of abundant $CO_2–N_2 \pm CH_4$ fluid inclusions associated locally to $H_2O–CO_2$–NaCl and H_2O–NaCl fluid inclusions (Schwartz et al., 1992; Klemd et al., 1993, 1996; Oberthür et al., 1994; Schmidt-Mumm et al., 1997; Yao et al., 2001).

Discovery of gold in the Birimian of NW Ghana, on the other hand, is much more recent. Here, alluvial and bedrock indications of gold were recognized during the early 1960s when the Gold Coast Geological Survey (Griffis et al., 2002) together with a Russian geological team carried out prospecting and mapping in the area, and outlined prospects in the Wa-Lawra greenstone belt and adjacent Koudougou-Tumu domain and the Julie belt. During further exploration for gold in 2006 and beyond, Azumah Resources Limited discovered 834,000 Oz of measured and indicated gold at 1.53 g/t with a reserve of 202,000 Oz at 2.84 g/t in the Julie deposit, in the Julie belt. To date, there has been no published data on the geology, alteration geochemistry along with the ore forming fluids and process associated with gold mineralization in the Julie deposit, nor on other deposits in NW Ghana.

The objective of this paper is to describe the geology and alteration geochemistry of the Julie deposit and to investigate the conditions of mineralization, in order to understand the mode of formation of the gold mineralization in the Julie deposit. These results are discussed and compared with those of previous studies from other deposits in Southern Ghana.

2. Regional geological setting

The Julie deposit is one of the numerous gold camps in the Wa-East district. This district is located within the Upper West region of Ghana, which lies on the eastern edge of the Paleoproterozoic Birimian terrane of the West African Craton (WAC) (Fig. 1).

This district formed during the 2250–1980 Ma Eburnean tectono-magmatic process that formed the greenstone belts and associated granitoids in the Birimian or Baoule-Mossi domain of the WAC (Feybesse et al., 2006). The Wa-East gold district occurs within the Julie Belt, which is bounded to the north by the Koudougou-Tumu granitoid domain, to the south by the Bole-Bulenga terrane, to the west by the N–S striking Wa-Lawra belt, and to the east by the Bole-Nangodi shear zone (Block et al., in press) (Fig. 2).

The Koudougou-Tumu domain is dominantly composed of 2156 ± 1–2134 ± 1 Ma old (U–Pb zircon ages; Agyei Duodu et al., 2009) tonalite–trondhjemite–granodiorite (TTG) intrusions, often present as orthogneisses, with some gabbroic intrusions. These rocks have been intruded by the 2128 ± 1 Ma and 2086 ± 4 Ma late pulse potassic porphyritic granites (U–Pb zircon ages; Taylor et al., 1992; Agyei Duodu et al., 2009). At the contact with the Koudougou-Tumu granitoid domain, the Julie belt is composed of basalts, gabbros and volcano-sediments.

The boundary between the Wa-Lawra belt (southern extent of the Boromo belt) and the Koudougou-Tumu granitoid domain (Fig. 2) is marked by the Jirapa fault and extends into the Boromo belt in Burkina Faso to the north. The Jirapa fault exhibits sinistral characteristics. The Wa-Lawra belt is predominantly composed of shales, greywackes, volcano-sediments, basalts and granitoids. Detrital zircon U–Pb dating of the volcanosediments in the Wa-Lawra belt gave ages older than 2139 ± 2 Ma (Agyei Duodu et al., 2009), which indicates that these volcano-sediments are probably older than some of the plutonic rocks in the Koudougou-Tumu domain. These volcano-sedimentary rocks have been intruded by granitoids with ages between 2124 ± 2 Ma and 2104 ± 1 Ma (U–Pb zircon ages; Agyei Duodu et al., 2009). South of the Julie belt, the Bole-Bulenga domain is composed of high grade metamorphic rocks termed as Buki gneisses composed mostly of meta-greywackes (de Kock et al., 2011). These rocks have been intruded by tonalite–trondhjemite–granodiorite (TTG) plutons usually exhibiting migmatitic texture and structures, which in turn have been cross-cut by the Bole-Nangodi NE shear zone.

3. Structure and metamorphic framework

The Birimian terrane in Ghana has been interpreted by Baratoux et al. (2011), Allibone et al. (2002), Feybesse et al. (2006), de Kock et al. (2011) and Block et al. (in press) to have a polyphase character. de Kock et al. (2011) proposed a short lived pre-Eburnean event in NW Ghana, which was termed Eoeburnean. The Eoeburnean event operated from 2160 Ma to 2150 Ma. The deformation associated to this event was driven by pluton emplacement and basin folding. In the Bole-Nangodi belt Eoeburnean structures strike N–S. The first Eburnean event according to Allibone et al. (2002) occurred between 2150 and 2110 Ma (according to U–Pb and Pb–Pb zircon ages on rhyolites and granitoids) and was termed Eburnean I. This same event was termed D_1 by Milési et al. (1989). According to Block et al. (in press) D_1 in NW Ghana occurred around 2137 ± 8 Ma (U–Pb monazite ages on the metasediments). The first Eburnean event is characterized by of magmatic accretion, volcanism, Birimian sedimentation and corresponds to a major phase in crustal thickening by nappe stacking and has experienced NE–SW shortening (Feybesse et al., 2006), N–S shortening (Perrouty et al., 2012) in southern Ghana and N–S shortening by Block et al. (in press) in northern Ghana. Metamorphism associated with this event has P–T conditions up to 450–650 °C and 4–6 kbar (Harcouët et al., 2007; John et al., 1999) in southern Ghana using the plagioclase–amphibolite geothermobarometry methods after Spear (1980), Plyusnina (1982) and Holland and Blundy (1994). Block et al. (in press), reported greenschist- to amphibolite-facies metamorphism associated with this event in NW Ghana using the P–T pseudosection method and geothermometry with a multi equilibria method. The amphibolite-facies regional metamorphism is characterized by pressures up to 11 kbar and temperatures up to 600 °C, whereas the greenschist-facies metamorphism occurred at temperatures between 230 °C and 350 °C and pressures between 1 and 3 kbar.

The second phase known as Eburnean II by Allibone et al. (2002) and $D_{2–3}$ by Feybesse et al. (2006) occurred around 2130–2110 Ma and 2090–1980 Ma (U–Pb and Pb–Pb zircon ages on rhyolites and granitoids). The tectonic style characterizing this event is a NE–SW transcurrent structures (Feybesse et al., 2006) and N- and NE-trending regional scale transcurrent faulting (Baratoux et al., 2011) which affected all lithologies within the Birimian in Ghana and SW Burkina Faso. This event is marked by greenschist-facies metamorphism with P–T conditions of 200–300 °C and 2–3 kbars and acts as a fluid pathway for mineralization (Feybesse et al., 2006; Block et al., in press). Gold mineralization has been reported along these transcurrent shear zones by Beziat et al. (2008), Allibone et al. (2002) and Feybesse et al. (2006).

Post Eburnean, late brittle NE–SW faults have been reported by Block et al. (in press) to have cross-cut all Eburnean structures in NW Ghana. These late faults have a limited extension and are steeply dipping normal faults. According to Block et al. (in press)