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Multistage gold mineralization in the Wa-Lawra greenstone belt, NW Ghana: The Bepkong deposit

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ABSTRACT

The Bepkong gold deposit is one of several gold camps in the Paleoproterozoic Wa-Lawra greenstone belt in northwest Ghana. These deposits lay along the Kunche-Atikpi shear zone, which is part of the larger transcurrent Jirapa shear zone. The formation of these shear zones can be attributed to the general ESE-WNW major shortening that took place in the Wa-Lawra belt. Gold mineralization in the Bepkong deposit mainly occurs within graphitic shales and volcaniclastic rocks. The ore consists of four N-S trending lenticular bodies, plunging steeply to the south, that are lithologically and structurally controlled. Their shape and thickness are variable, though a general strike length of 560 m and an overall thickness of 300 m can be defined. An alteration mineral assemblage characterises the ore, and consists of chlorite-calcite-sericite-quartz-arsenopyrite-pyrite. Pyrite, as distinct from arsenopyrite, is not limited to the altered rocks and occurs throughout the area. At Bepkong, gold is associated with arsenopyrite and pyrite, which occur disseminated in the mineralized wall rock, flanking Type-1 quartz veins, or within fractures crossing these veins. Textural observations indicate the early formation of abundant arsenopyrite, followed by pyrite, with chalcopyrite, galena, sphalerite and pyrrhotite occurring as inclusions within pyrite and altered arsenopyrite. Detailed petrography, coupled with SEM, LA-ICP-MS and EMP analyses, indicate that gold in the Bepkong deposit occurs in three distinct forms: (i) invisible gold, mostly in arsenopyrite (ii); visible gold as micron-size grains within fractures and altered rims of arsenopyrite, as well as at the interface of sulphide grains; (iii) free visible gold in fractures in quartz veins and their selvages. We interpret the invisible gold to have co-precipitated with the early-formed arsenopyrite. The small visible gold grains observed within the sulphide interfaces, altered arsenopyrite, fractures and grain boundaries, are interpreted to have formed as a result of the dissolution and redistribution of the invisible gold during later alteration of arsenopyrite, which took place at lower temperatures during crenulation and fracturing accompanying late deformation, and was accompanied by pervasive pyritization of the wall rock.

1. Introduction

Greenstone belts all over the world have been prospective regions for orogenic gold deposits for many decades now (Davis and Zaleski, 1998), and account for an important amount of the world's total gold production (a recent figure indicates about 13% of global production, corresponding to 15,920 metric tonnes of Au; Dubé and

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Gosselin, 2007). Well known world-class occurrences include Kalgoorlie in Australia, the Abitibi region in Canada, the Ashanti deposits in Ghana, and Mother Lode in the USA (e.g., Groves et al., 1998). These deposits are usually associated with first-order regional shear zones and are commonly situated on second- or third-order faults that splay off these first-order structures (Groves et al., 1988; Eisenlohr et al., 1989). In southern Ghana, gold mineralization has been identified with greenstone belts and has been reported to occur along broad shear zones and in narrow faults immediately adjacent to less deformed rocks (Appiah, 1991; Eisenlohr and Hirdes, 1992; Allibone et al., 2002, 2004). This region hosts some of the largest deposits of this kind, as exampled by the Obuasi mine (AngloGold Ashanti), the Ahafo mine (Newmont Mining Corporations), the Damang mine (Goldfields Limited), the Bibiani mine (Noble Mineral resources), and the Bogoso/Prestea which total over 40 million ounces (Oz) of gold. Therefore, the majority of geological studies on gold mineralization in Ghana have focussed on them (Junner, 1932, 1935, 1940; Kesse, 1985; Milesi et al., 1989, 1992; Leube et al., 1990; Blenkinsop et al., 1994; Davis et al., 1994; Oberthür et al., 1994, 1996, 1998; Mumin and Fleet, 1994; Hammond and Tabata, 1997; Klemd and Hirdes, 1997; Barritt and Kuma, 1998; Yao and Robb, 2000; Feybesse et al., 2006; White et al., 2015).

However, with gold mining being the major driver of the Ghanaian economy, profitable (<1 million ounces) albeit not exceptional gold deposits cannot be overlooked, making the Birimian in NW Ghana an important area to study. In this region, numerous gold exploration prospects have been identified, particularly in the N-S Wa-Lawra greenstone belt. These include the Kunche, Bepkong, Atikpi, Yagha, Basabli and Duri prospects (Fig. 1), although only Kunche (309,000 Oz measured and indicated resource) and Bepkong (113,000 Oz measured and indicated resource) are of economic importance. These two deposits are at a stage of advanced exploration to pre-production, by the Azumah Resources Limited Company. This paper investigates the gold mineralization and its relationships with deformation in the Bepkong deposit. We highlight the geological and structural controls on gold mineralization and reconstructs the ore genesis via mineralogical, geochemical, fluid inclusion studies and propose a metallogenic model for the gold mineralization.

2. Regional geology of the Wa-Lawra belt

The N-S trending Wa-Lawra belt in NW Ghana is part of the Paleoproterozoic Birimian terrane of the West African Craton (WAC; Fig. 1) and is the only N-S trending belt in Ghana (Kesse, 1985; Samokhin and Lashmanov, 1991; Pobedash, 1991; Roudakov, 1991). The belt is the southern portion of the larger Boromo belt in Burkina Faso (Béziat et al., 2000; Baratoux et al., 2011). It is composed of metamorphosed shales, greywackes, volcano-sediments, basalts, dacites, andesites, granites, para and ortho-gneisses and granitoids (Fig. 1). According to Feybesse et al. (2006), the Birimian rocks in Ghana were formed between 2250 and 1980Ma.

Regionally, the Wa-Lawra-Boromo belt is bounded to the west by the Diebougou-Bouna granitoid domain in Burkina Faso and to the east by Koudougou-Tumu granitoid domain (KTGD). The contact between the Wa-Lawra belt and the KTGD is marked by the Jang shear zone (Fig. 1).

The Wa-Lawra belt can be subdivided into eastern and western parts. The boundary between the eastern and western parts is marked by the crustal-scale sinistral Jirapa shear zone (Block et al., 2015b) which extends into Burkina Faso. The western part of the Wa-Lawra belt is composed mainly of sediments (shales, greywackes, and volcano-sediments), volcanic rocks and intruded granitoids and the eastern part is mainly composed of granites, para and ortho-gneisses, rhyolites and granitoids (Amponsah et al., 2015a,b).

According to Baratoux et al. (2011) the volcanics and pyroclastic flows in the belt were emplaced between 2200 Ma to 2160 Ma. Detrital zircon age dating of the volcano-sediments in the Wa-Lawra belt gave ages older than 2140 Ma and syn-tectonic to late kinematic granitoid intrusion in the belt were emplaced around ~2150 and 2100 Ma, respectively (Agyei Duodu et al., 2009).

The volcanic suites and sediments west of the Jirapa shear zone have been metamorphosed under greenschist facies conditions whilst the granitoids and para-ortho gneisses to the east have undergone amphibolite facies metamorphism. The metamorphic mineral assemblages associated to the greenschist facies metamorphism consist of chlorite, calcite and epidote whilst the amphibolite facies are garnet, plagioclase, clinopyroxene and hornblende (Block et al., 2015a).

A polyphase deformation history has been proposed by Baratoux et al. (2011) and Block et al. (2015b) for the Boromo belt, including the Wa-Lawra belt. The first deformation event in N Ghana corresponds to N-S shortening under upper greenschist at the limit with blueschist to amphibolite facies conditions (Block et al., 2015b). This early deformation event was recorded in southern Ghana (Perrouty et al., 2012) and northern Burkina Faso (Tshibubudze and Hein, 2013; McCuaig et al., in review) but no unequivocal evidence was found in SW Burkina Faso (Baratoux et al., 2011). The D_2 deformation phase (D_1 according to Baratoux et al., 2011) formed N to NNW trending S_2 penetrative foliation. The D_2 event is marked by vertical dipping metamorphic penetrative foliation which is often parallel to primary bedding within the sediments. The metamorphic grade varies between the greenschist and amphibolite facies. Extensive domains reaching migmatite facies during D_2 were found in the Bole region in northwestern Ghana (Block et al., 2015a). Subsequent E-W shortening lead to the folding and overprinting of the S_1 and S_2 penetrative metamorphic foliation by a N-S trending schistosity S_3. These structures were transected by S_4 and S_5 transcurrent shear zones which affected all the Birimian volcanic and volcano-sedimentary units and structured most of the syn-tectonic and early magmatic rocks. The D_4 shear zones are N-S oriented sinistral while the D_5 shear zones are NE oriented dextral, with shallow dipping lineations. Gold mineralization has been reported along these shear zones. The majority of the D_4 and D_5 shear zones formed under lower to upper greenschist facies conditions. Amphibolite facies ductile shear zones occur at the contact aureoles of syn-kinematic granitoids (Baratoux et al., 2011). The S_4 and S_5 shear zones are generally brittle to brittle-ductile compared to majority of S_1 to S_3, which are mostly ductile and schistose in nature, suggesting S_4 and S_5 shear zones operated at lower temperatures with respect to the previous deformation events. The D_4 and D_5 are associated to WNW-ESE and E-W shortening, respectively. Late E-W tension gashes and NE-oriented steeply dipping brittle faults formed under brittle conditions and E-W shortening and are ascribed to the D_6 event (Block et al., 2015a). These late brittle structures have only limited extension. The veins sometimes contain chlorite, white mica or epidote minerals. The last deformation event D_7 only affects highly anisotropic lithologies and is characterized by subvertical NW-striking crenulation cleavage related to NE-SW shortening.

3. Methodology

Gold mineralization at the Bepkong deposit does not appear in outcrop, as the area is entirely covered with transported alluvium and colluvium. All geological information was obtained from logging of reverse circulation (RC) drilling chips (which form the