



The Kalana vein-hosted gold deposit, southern Mali



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ABSTRACT

The Kalana gold deposit occurs within metamorphosed Paleoproterozoic volcano-sedimentary series of the Birimian Baoulé-Mossi domain of the West African Craton, in the south of Mali. These formations are intruded successively by small dioritic bodies, as well as andesitic and tonalitic dykes, which exhibit volcanic arc-setting signatures. Mineralization is hosted by two sets of quartz veins that intersect the regional schistosity. The first set of veins is the most important in terms of grades and size, and consists of thick veins (up to meter size) that range in trend from N–S to E–W with shallow plunges. The second set consists of much thinner (centimeter size) sub-vertical quartz veins oriented NE–SW. The two sets of veins are interpreted to have formed during the evolution of late, gently dipping thrust faulting. Two episodes of gold precipitation are recognized: a first episode, during early stages of vein growth, formed micron-size native gold inclusions in arsenopyrite; a later episode, during vein shearing and fracturing of the quartz lodes, precipitated native gold in free form in quartz, in fractured arsenopyrite, and associated with chalcopyrite, galena, sphalerite, Bi sulfides and native bismuth. All evidence suggests that the Kalana deposit represents orogenic gold mineralization formed during a relatively long-lived hydrothermal system, at a late stage of the tectonic history of the greenstone belt.

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1. Exploration history and introduction

The Paleoproterozoic domain of the West African Craton (WAC) encloses numerous economic gold deposits, including world famous Obuasi in the Kumasi basin (Ghana), the most important gold producer in West Africa and one of the largest gold mines in operation worldwide (e.g., Oberthür et al., 1994; Allibone et al., 2002). Mali is second to Ghana as leading gold producer in West Africa, with world-class deposits such as Morila and Syama to the south, and Sadiola, Yatela and Loulo to the southwest, in the Kédougou-Kéniéba inlier (e.g., Hammond et al., 2011; McFarlane et al., 2011; Lawrence et al., 2013). The Kalana gold deposit is located in the south of Mali, at some 60 km north of the junction between the borders of Mali, Guinea and Ivory Coast (Fig. 1), about 300 km south of Mali's capital Bamako. This deposit represents an important source of gold in the country and an interesting case to investigate, as its geological and mineralogical characteristics depart from those of most other greenstone belt-hosted gold deposits in the WAC. This contribution resumes the exploration and mining operation history of the deposit, provides an overview of its general geological context, presents its structural setting, and describes the mineralogical and textural features of the ore. The similarities and differences with other orogenic gold deposits in West Africa are also briefly discussed.

As is commonly the case in western Africa, alluvial placers in the Kalana region had been exploited by artisanal mining methods long before the mine existed. The first known occurrence of primary gold was reported during regional exploration in 1931, and consisted of a high-grade quartz vein in an artisanal pit (Buro et al., 1996). Systematic exploration in the area was undertaken during a period from 1967 to 1982, by the Malian companies *Société Nationale de Recherche et d'Exploitation Minière* (SONAREM) and *Société de Gestion et d'Exploitation des Mines d'Or de Kalan* (SOGEMORK), under Soviet supervision. Production commenced in 1985 and lasted until 1991, during which time the mine produced approximately 81,000 oz of gold (227,000 t extracted at an average grade of 13 g/t Au, with an average recovery of 85.4%). Assisted by the World Bank, in 1994 the Malian government decided to privatize the property, and in 1995 Ashanti Gold Fields Co. Ltd. and Johannesburg Consolidated Investments Ltd. (JCI) joined venture on the Kalana exploitation permit, with a 20% interests remaining to the Malian government. However, JCI withdrew a year later and over the following eight years several companies alternated on the rights to the property, until, at the end of 2002, Avnel Gold Mining Ltd. acquired the Kalana Exploitation Permit from the Malian government. Within two years, the mine was back in operation. Avnel entered into a 3-year agreement with IAMGOLD Corporation in 2009 and, in March 2013, Avnel regained full project ownership. At present, underground workings extend to 180 m depth, but drillings pulled mineralized intercepts at depths of 600 m. Reserves totaled only 26,000 t grading 6.75 g/t

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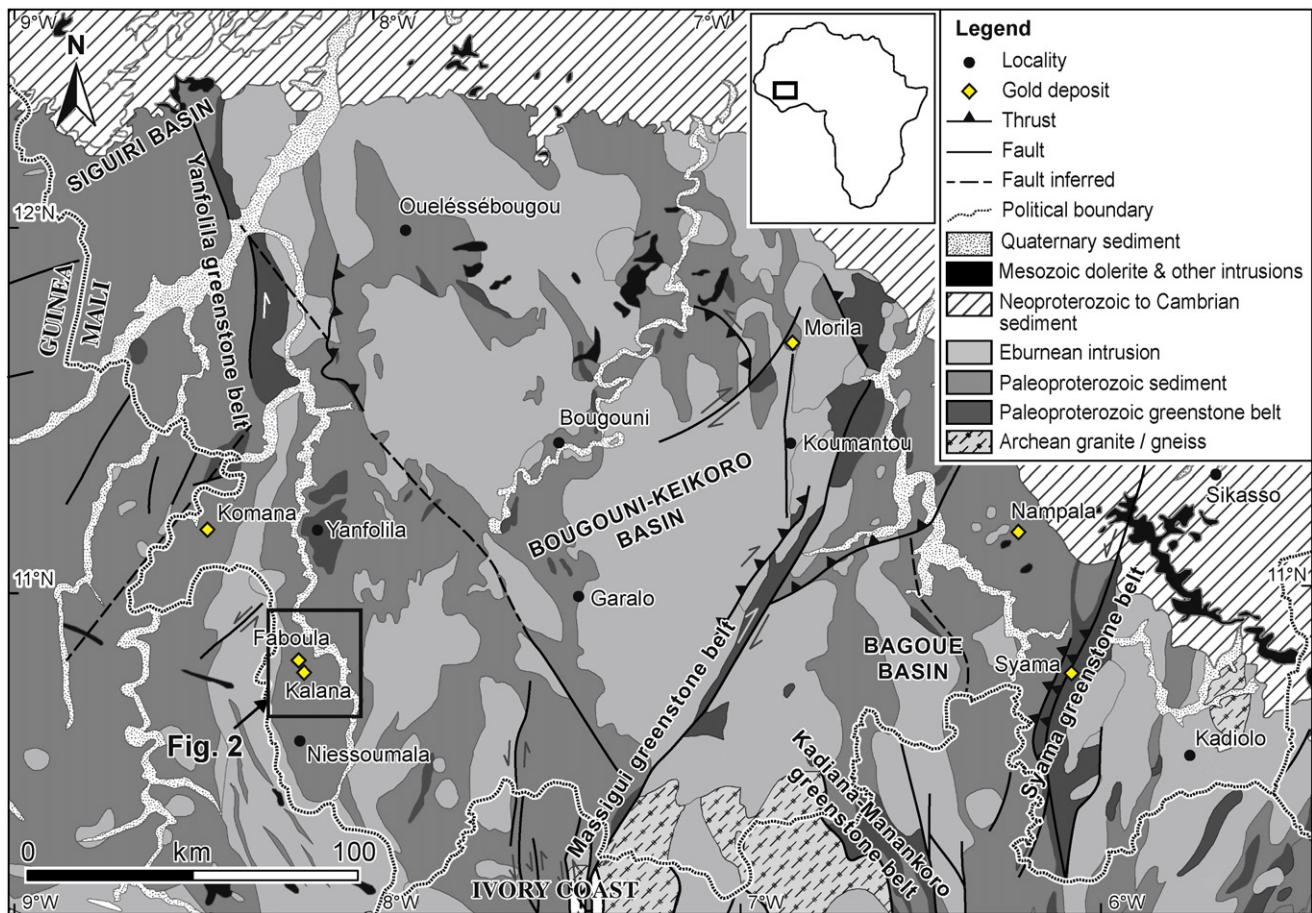


Fig. 1. Simplified geological map of the Baoulé-Mossi domain in southern Mali (modified after Milési et al., 2004). The study area is located (expanded in Fig. 2), and the inset places the map within the African continent.

gold in September 2014 (Northern Miner, 2014), however, later that year the company reported a resource estimate for an open-pit operation near the underground mine, with 2.11 Moz grading 4.52 g/t, and

an inferred resource of 0.31 Moz grading 5.28 g/t (cf., Table 1 for total resources) (Avel Gold Mining Ltd., 2015).

2. Geological characteristics

The southernmost reaches of Mali are part of the Paleoproterozoic Baoulé-Mossi domain of the West African Craton, which is covered by the large Taoudeni basin to the north. The Baoulé-Mossi domain consists mostly of Birimian volcano-sedimentary belts intercalated with granitoids, formed between 2250 and 1800 Ma (Feybesse et al., 2006). These rocks were strongly deformed by the Eburnean Orogeny (Bonhomme, 1962; Baratoux et al., 2011).

Within the Baoulé-Mossi domain, the Kalana deposit lies in the Bougouni-Keikoro sedimentary basin, to the south of the Yanfolila greenstone belt (Bassot and Traoré, 1988) (Fig. 1). The area underwent strong weathering and is now covered by a lateritic profile that ranges from 40 to 70 m in thickness. Consequently, the geological information on the deposit was mostly obtained from drill core samples and underground galleries. The main lithology in the vicinity of the deposit consists of volcano-sedimentary series, comprising flysch, basic and acid volcano-sediments (Fig. 2), which are all metamorphosed to greenschist facies. Rock types in the deposit area comprise microconglomerate, sandstone, siltstone and graphitic pelite, interbedded with volcanic glass and ash. A small dioritic body, composed of plagioclase, hornblende, biotite and interstitial quartz, intrudes these series (Fig. 3). Whole-rock data indicate a diorite to alkaline-diorite composition, with important contents of Cr and Ni (up to 1190 and 285 ppm, respectively), and a calc-alkaline character (Sangaré et al., in press). Several dykes of andesitic to basalt-andesitic composition intersect the metasediments and the

Table 1
General information on the Kalana deposit.

Deposit name	Kalana
Commodity of exploitation	Au
Location	S Mali
Longitude–latitude [dec. degrees]	10.800030° N–8.194939° W
Geographic location	Sikasso Region of Southern Mali. The deposit is situated some 40 km south of the town of Yanfolila and 200 km south of Bamako.
Geological location	West African Craton; Leo-Man Shield, Baoulé–Mossi domain in the Bougouni-Keikoro basin, between the Yanfolila and Massigui greenstone belts.
Deposit status	Active mine
Deposit type	Late-orogenic; quartz vein hosted, related to a dioritic body.
Current owner	Avel Gold Mining Limited
Average grade	4.40 g/t (March 2015; mineral resource estimation).
Tonnage	March 2015: total indicated resources of 2.15 Moz (at 4.40 g/t) and inferred resources of 0.38 Moz (at 5.33 g/t).
Past production	In the periods from 1985 to 1991 and 2004 to March 2014, 81,000 and 150,000 oz of gold were produced, respectively.

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