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The Yatela gold deposit: 2 billion years in the making

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ABSTRACT

Gold mineralisation in the Yatela Main gold mine is hosted in a saprolitic residuum situated above Birimian supracrustal rocks, and at depth. The supracrustal rocks comprise metamorphosed calcitic and dolomitic marbles that were intruded by diorite (2106 ± 10 Ma, $^{207}Pb/^{206}Pb$), and sandstone-siltstone-shale sequences (youngest detrital zircon population dated at 2139 ± 6 Ma). In-situ gold-sulphide mineralisation is associated with hydrothermal activity synchronous to emplacement of the diorite and forms a sub-economic resource; however, the overlying saprolitic residuum hosts economic gold mineralisation in friable lateritized palaeosols and aeolian sands (loess).

Samples of saprolitic residuum were studied to investigate the morphology and composition of gold grains as a proxy for distance from source (and possible exploration vector) because the deposit hosts both angular and detrital gold suggesting both proximal and distal sources. U–Pb geochronology of detrital zircons also indicated a proximal and distal source, with the age spectra giving Archaean (2.83–3.28 Ga), and Palaeoproterozoic (1.95–2.20 Ga) to Neoproterozoic (1.1–1.8 Ga) zircons in the Yatela depocentre. The 1.1–1.8 Ga age spectrum restricts the maximum age for the first deposition of the sedimentary units in the Neoproterozoic, or during early deposition in the Taoudeni Basin. Models for formation of the residuum include distal and proximal sources for detritus into the depocentre, however, it is more likely that material was sourced locally and included recycled material. The creation of a deep laterite weathering profile and supergene enrichment of the residuum probably took place during the mid-Cretaceous-early Tertiary.

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1. Introduction

The Yatela goldfield is situated in the Kédougou-Kéniéba Inlier (KKI) of the West African Craton (WAC) (Boshoff et al., 1998; Ranson, 1998; Wilson, 2002). The goldfield hosts several open cast mines that exploited and produced gold, largely from the Yatela Main deposit, Yatela North, Alamoutala and KW 18 pits (Fig. 1). The Yatela operations are mined and managed by Anglogold Ashanti and joint owned by IAMGold and the Malian government through the Société d'Exploitation des Mines d'Or de Sadiola S.A. (SEMOS).

The general geology of the Yatela goldfield includes steeply west dipping calcitic and dolomitic marble, which is unconformably overlain by a sandstone-siltstone-shale sequence and intruded by a diorite dyke. These rocks are crosscut by a series of narrow shear zones that host primary hydrothermal gold mineralisation of sub-economic to economic importance. In turn, the supracrustal rocks and shear zones are unconformably overlain by an auriferous dissolution residue (i.e., saprolitic residuum) that formed a mineable resource at Yatela Main.

The focus of this research has been the Yatela Main deposit. As described by Hanssen et al. (2004) who gave the first account, interpretation and genetic model for Yatela Main, primary hydrothermal gold mineralisation is hosted at the sheared contact between marble and a weakly mineralised diorite intrusion (Anglogold Ashanti, 2010). Above this, the saprolitic residuum developed during a period of sustained rock decomposition and weathering, with karstification of the carbonate unit, development of a karst morphology, and concentration of gold (Hanssen et al., 2004). Karstification accompanied subsidence and infill with detritus sourced from surrounding rock units. Importantly, the auriferous residuum forms part of the resources and reserve

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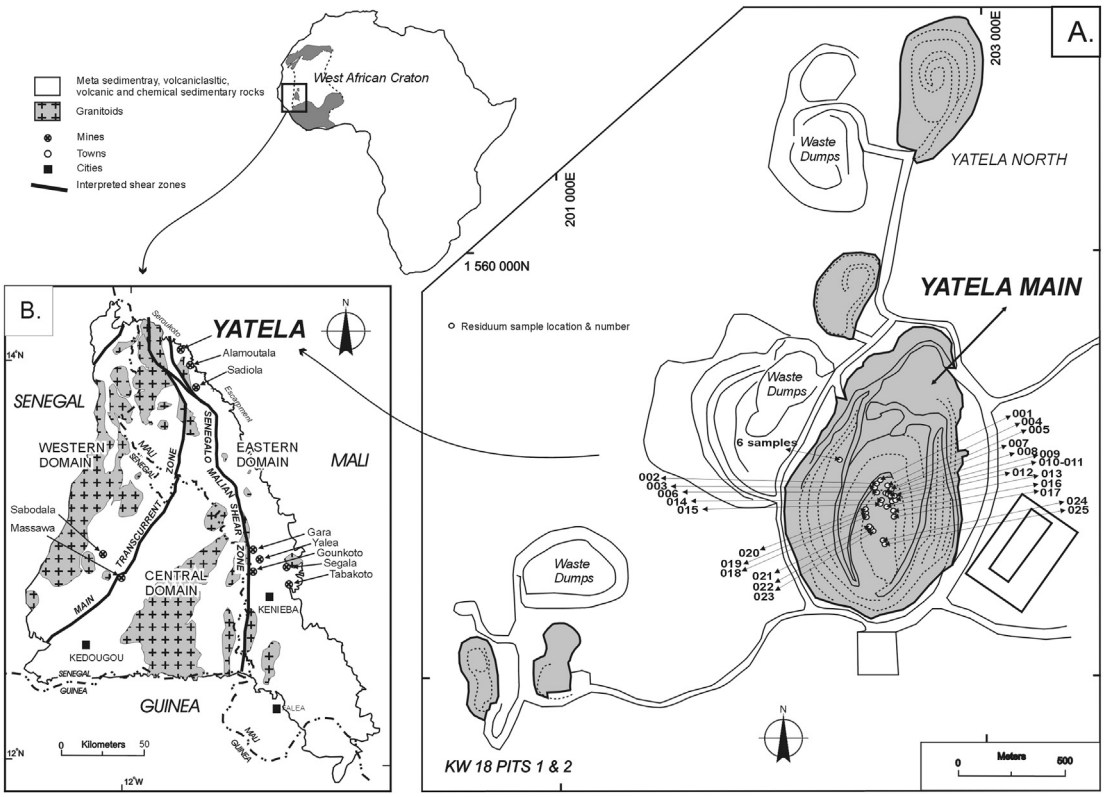

Fig. 1. Location maps of the Yatela Main deposit (A), and significant gold deposits in the Kédougou-Kéniéba Inlier of West Africa (B). The layout of the Yatela mine site with Yatela Main, Yatela north and KW18 open casts 1 and 2 are marked. The locations of 25 samples of residuum are also indicated; they were collected from the −113 to −116 level (~220–225 m below land surface). The KW pit 1 and 2 open casts are situated approximately 5.5 west of Yatela Main and host gold mineralisation in breccia veins in a northerly trending thrust faults.

portfolio of the Yatela Main deposit providing an interesting and unique exploration target in the WAC. The total mineral resources for Yatela Main were reported at 1.18 million tonnes at 2.56 g/t by AngloGold Ashanti in 2010. The mine was decommissioned on 30 September 2013.

Various styles of gold mineralisation occur in Mali and these include gold in laterites in southern Mali (Freyssinet et al., 1989). In the KKI, gold mineralisation in the Loulo goldfield is hosted in 1) stratabound sulfide disseminations or ankerite-rich stockwork veins in folded tourmalinized sandstones (Fouillac et al., 1993), and 2) quartz ± ankerite lodes and disseminated sulphide stringer zones (Lawrence et al., 2013), while the Gounkoto deposit is hosted in a northerly trending shear zone with a lower grade footwall. Au–As–Sb mineralisation at the Sadiola Hill deposit is carbonate-hosted (Hanssen et al., 2004; Robertson, 2004), with ore-forming processes taking place at ca. 2090 Ma to 2060 Ma during the Eburnean tectono-magmatic event (Masurel et al., in press). The bulk of the ore is hosted within a 10–50 m wide brittle-ductile dilational shear zone defined as the Sadiola Fracture Zone.

In contrast to these deposit styles, gold mineralisation at the Yatela Main is unique with respect to that encountered elsewhere in the West African Craton (WAC) because the deposit forms both an in-situ, low-grade gold occurrence that is hosted in rocks of the Birimian Supergroup (ca. 2200–2050 Ma in the KKI), and an overlying high-grade residuum derived from the in-situ low-grade source. Our field studies in the Yatela Main open cast over several field seasons generally agrees with the stratigraphy of Hanssen et al. (2004) that the auriferous Birimian protolith is sequentially overlain by 1) a medium-grained friable brown–red–yellow auriferous saprolitic residuum, 2) a sandy to gritty saprolite that hosts blocks and boulders of marble, sandstone and mudstone (blocky sand unit), and is weakly to moderately well-bedded; 3) a yellow sand unit; 4) reworked pisolithic laterite; and 5) a bedded alluvial cover sequence. (For convenience, we refer to the sequence above the residuum as the Upper Sedimentary Cone or USC.)

However, two points are noteworthy. As stated by Hanssen et al. (2004) sandstone blocks in the 'blocky sand unit' are very similar to sandstone blocks of the Seroukoto Sandstone. The Sandstone was deposited in the Neoproterozoic as coarse grained sand intercalated with conglomerate lens, and forms part of the Hassanah-Diallo Formation of Shields et al. (2007) suggesting a younger than Neoproterozoic age for the blocky sand unit. An escarpment exposing the sandstone is situated immediately east and north of Yatela Main open cast.

Additionally, the presence of reworked laterite in the USC is important. Lateritic deposits across West Africa formed during a long period of tropical morphogenesis that was initiated in the mid-Cretaceous to early Palaeogene after breakup of the Gondwana supercontinent (Brown et al., 1994; Lavaud et al., 2004). These laterite deposits were reworked during the Palaeocene to Miocene (~59–11.5 Ma; ^{39}Ar–^{40}Ar dating of generations of cryptomelane) (Beauvais et al., 2008; Beauvais and Chardon, 2013). It is therefore possible that USC and auriferous residuum at Yatela formed over a considerable period of Earth's history from the Palaeoproterozoic to the Miocene (or 2 Ga) leaving open the possibility that formation of the saprolitic residuum within the Yatela open cast, with concomitant concentration of gold, was a lengthy process.

In this study, we present and summarise the results of geological investigations of the Yatela Main (residuum) deposit because the deposit style provides a new exploration target in the WAC. We investigate the morphology and geochemistry of gold grains in samples taken from the residuum as a proxy for distance from

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