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Geology, geodynamics and orogenic gold prospectivity modelling of the Paleoproterozoic Kumasi Basin, Ghana, West Africa

Bijal Chudasama [a,*], Alok Porwal [a,b], Oliver P. Kreuzer [c,d], Kris Butera [c]

[a] Centre of Studies in Resources Engineering, Indian Institute of Technology Bombay, Powai, 400076, India
[b] Centre for Exploration Targeting, University of Western Australia, Crawley, 6009 WA, Australia
[c] Corporate Geoscience Group, PO Box 5128, Rockingham Beach, WA 6969, Australia
[d] Economic Geology Research Centre, James Cook University, Townsville, QLD 4811, Australia

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ABSTRACT

This paper describes the geology and tectonics of the Paleoproterozoic Kumasi Basin, Ghana, West Africa, as applied to predictive mapping of prospectivity for orogenic gold mineral systems within the basin. The main objective of the study was to identify the most prospective ground for orogenic gold deposits within the Paleoproterozoic Kumasi Basin. A knowledge-driven, two-stage fuzzy inference system (FIS) was used for prospectivity modelling. The spatial proxies that served as input to the FIS were derived based on a conceptual model of gold mineral systems in the Kumasi Basin. As a first step, key components of the mineral system were predictively modelled using a Mamdani-type FIS. The second step involved combining the individual FIS outputs using a conjunction (product) operator to produce a continuous-scale prospectivity map. Using a cumulative area fuzzy favourability (CAFF) curve approach, this map was reclassified into a ternary prospectivity map divided into high-prospectivity, moderate-prospectivity and low-prospectivity areas, respectively. The spatial distribution of the known gold deposits within the study area relative to that of the prospective and non-prospective areas served as a means for evaluating the capture efficiency of our model. Approximately 99% of the known gold deposits and occurrences fall within high- and moderate-prospectivity areas that occupy 31% of the total study area. The high- and moderate-prospectivity areas illustrated by the prospectivity map are elongate features that are spatially coincident with areas of structural complexity along and reactivation during D4 of NE–SW-striking D2 thrust faults and subsidiary structures, implying a strong structural control on gold mineralization in the Kumasi Basin. In conclusion, our FIS approach to mapping gold prospectivity, which was based entirely on the conceptual reasoning of expert geologists and ignored the spatial distribution of known gold deposits for prospectivity estimation, effectively captured the main mineralized trends. As such, this study also demonstrates the effectiveness of FIS in capturing the linguistic reasoning of expert knowledge by exploration geologists. In spite of using a large number of variables, the curse of dimensionality was precluded because no training data are required for parameter estimation.

1. Introduction

The Birimian metavolcanic and metasedimentary successions of Ghana form part of the Paleoproterozoic West African Craton that also underlies much of Burkina Faso, Niger, Cote d'Ivoire, Mali, Sierra Leone, Liberia, Guinea, and Senegal. Some of the world's largest gold deposits are localised along a network of shear zones and faults that cut the Paleoproterozoic Birimian Supergroup of West Africa (Allibone et al., 2002b). Much of this mineral wealth is concentrated in Ghana, the second largest gold producer in Africa (Brown, 2015). The main gold belts in southwestern Ghana are the Ashanti Belt (total endowment ca. 170 Moz Au), the Sefwi–Bibiani Belt (>30 Moz Au) and the Asankrangwa Belt (>10 Moz Au) (Fig. 1; Table 1).

Compared to the established gold belts, such as Ashanti and Sefwi–Bibiani, exploration activities within the Asankrangwa Belt (Fig. 2a) and enclosing Kumasi Basin have been limited and mainly focused around artisanal and past colonial operations. Possible explanations for the scarcity of detailed exploration are: (1) extensive recent alluvial and colluvial cover, and (2) relatively poor knowledge of the geology and structure of the Kumasi Basin. Moreover, (3) it was not until the mid-1990s that the gold potential of the Asankrangwa Belt (a shear zone along the central axis of the Kumasi Basin, Fig. 2a) was fully recognised.

The discovery in 2006 by Asanko Gold Inc. of the outcropping Esaase gold deposit (Table 1) illustrates the potential of the

* Corresponding author.

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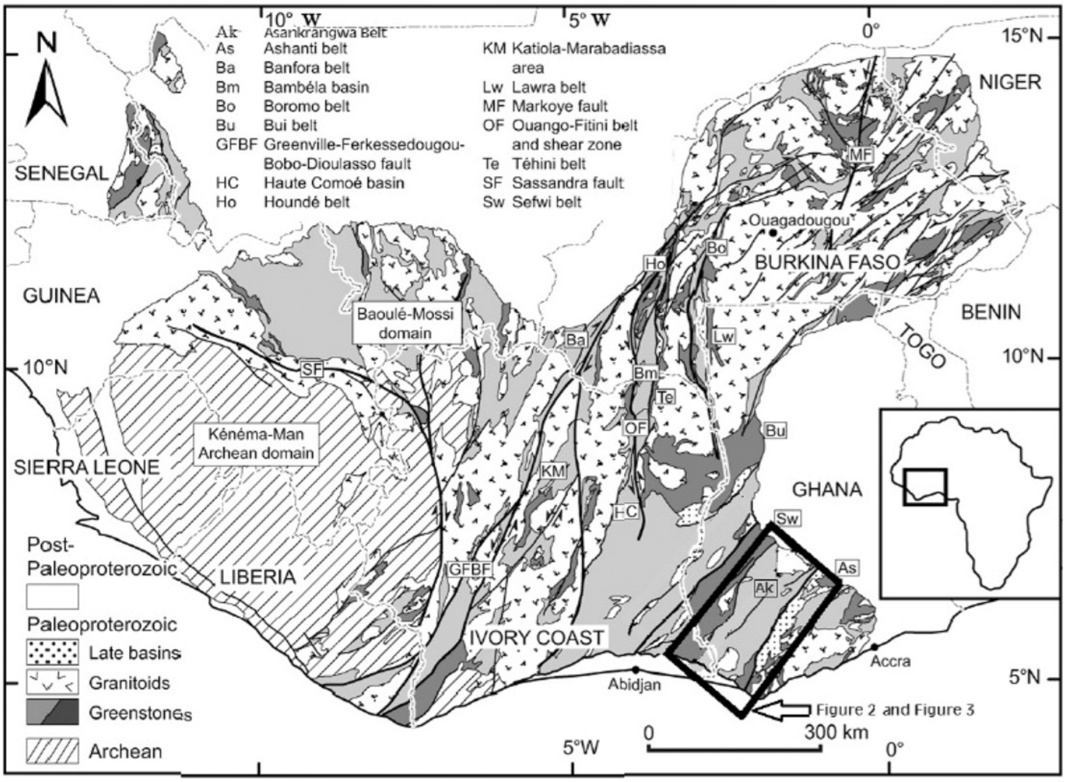

Fig. 1. Study area: Kumasi Basin — location and extent (Jessell et al., 2012); the rectangle marks the area shown in Figs. 2 and 3.

Asankrangwa Belt and wider Kumasi Basin to yield further multi-million ounce gold deposits. Based on this premise, Asanko Gold Inc. commissioned Corporate Geoscience Group to undertake a geological framework, prospectivity and targeting study of this emerging and potentially well-endowed belt. The work undertaken by Corporate Geoscience Group in close collaboration with Asanko Gold Inc.'s technical team resulted in (1) new geological syntheses and interpretations of the Asankrangwa Belt and wider Kumasi Basin, (2) a better understanding of the controls on gold mineralization, and (3) an updated conceptual model. This input was crucial for the subsequent GIS-based gold prospectivity modelling employing both data-driven weights of evidence (Miller et al., in press) and knowledge-driven fuzzy inference system (FIS) approaches.

A two-stage, knowledge-driven, Mamdani-type fuzzy inference system (FIS) was implemented to model the orogenic gold prospectivity in the Kumasi Basin. The key components of the mineral system were modelled in the first stage FIS, and their outputs were combined using a conjunction operator in the second stage in order to derive the prospectivity map. The FIS model aims to capture the linguistic reasoning of exploration geologists in the form of fuzzy if–then rules and objective mathematical functions, rather than in the form of explicit class weights and map weights as in traditional fuzzy models.

Table 1
Grade and resource figures for selected, significant gold deposits and camps in Ghana.

Deposit/camp	Region	Average grade[a] (g/t Au)	Current resouce[b] (oz Au)	Historic production[c]	Total endowment[d]	References
Obuasi	Ashanti Belt	5.32	27,360,000	29,500,000	56,860,000	AngloGold Ashanti (2014), SRK Consulting (2008)
Tarkwa	Ashanti Belt	1.15	9,568,000	9,700,000	19,268,000	Gold Fields (2014, 2015)
Ahafo	Sefwi–Bibiani Belt	1.96	10,120,000	5,000,000	15,120,000	Newmont (2014a)
Prestea	Ashanti Belt	4.79	1,084,000	9,000,000	10,084,000	www.gsr.com
Iduapriem	Ashanti Belt	1.39	6,610,000	2,850,000	9,460,000	AngloGold Ashanti (2014)
Damang	Ashanti Belt	1.92	5,260,000	4,100,000	9,360,000	Gold Fields (2014, 2015)
Edikan	Kumas Basin	1.10	7,411,000	600,000	8,011,000	www.perseusmining.com.au
Akyem	Ashanti Belt	1.72	7,180,000	?	7,180,000	Newmont (2014b)
Esaase	Asankrangwa Belt	1.45	5,910,000	0	5,910,000	www.asanko.com
Bibiani	Sefwi–Bibiani Belt	3.40	1,700,000	4,000,000	5,700,000	Resolute Mining (2014a,b)
Wassa	Ashanti Belt	2.21	3,519,000	1,277,422	4,796,422	www.gsr.com
Nkran	Asankrangwa Belt	2.34	3,470,000	590,000	4,060,000	www.asanko.com, SRK Consulting (2011)
Chirano	Sefwi–Bibiani Belt	2.46	2,271,000	1,264,626	3,535,626	www.kinross.com
Bogoso	Ashanti Belt	2.74	2,000,000	1,108,234	3,108,234	www.gsr.com, SRK Consulting (2014)
Konongo	Ashanti Belt	3.80	942,000	1,600,000	2,542,000	Signature Metals (2015)
Nzema	Ashanti Belt	1.30	1,900,000	400,000	2,300,000	www.endeavourmining.com

[a] For current resources only.
[b] Most recent, publically available global resource figures including Measured, Indicated and Inferred Resources and Reserves.
[c] If applicable and/or reported. Many of the historic production figures are incomplete.
[d] Sum of current resource and historic production.