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Mineralogical and structural controls on gold mineralization in the Ashanti greenstone belt

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Abstract

Picture a narrow shear zone cutting through two-billion-year-old volcanic rock—within that deformation corridor, gold concentrations can jump from background levels of 5 parts per billion to economic grades above 8 grams per tonne in less than a metre. This research examined the mineralogical and structural controls on gold distribution across three mine sites in the Ashanti Greenstone Belt of southern Ghana, one of West Africa's most prolific gold provinces. A total of 128 drill-core samples were collected and analysed by reflected-light and scanning-electron microscopy, whole-rock geochemistry (fire assay Au; ICP-MS multi-element), and structural logging. Gold mineralisation was found to be concentrated in arsenopyrite-bearing quartz veins hosted within second-order shear zones that splay off the main Ashanti fault. Mean gold grade in shear-zone cores reached 8.74 g/t, compared with 2.13 g/t in disseminated sulphide zones away from structures. Arsenic showed the strongest geochemical association with gold ($r = 0.91$), followed by sulphur ($r = 0.83$) and antimony ($r = 0.76$). The results confirm that structural preparation—particularly dilatant jogs within shear networks—exerts first-order control on ore-shoot geometry, while arsenopyrite acts as the principal gold-hosting mineral phase.

Keywords: Gold mineralization, greenstone belt, structural controls, mineralogy, ore genesis, Ashanti, arsenopyrite, shear zone, geochemistry, West Africa

Introduction

A recurring scenario in West African gold exploration goes something like this: a regional geochemical survey flags an anomaly, trenching confirms visible gold in quartz veins, and a drill programme begins. But the veins pinch and swell unpredictably, and without a structural model, half the holes miss the ore. The Ashanti Greenstone Belt has been mined for over a century, yet the interplay between mineralogy and structure that governs where gold concentrates remains incompletely documented at the deposit scale ^[1].

The belt is a northeast-trending Paleoproterozoic sequence of metavolcanic and metasedimentary rocks intruded by granodiorite and cut by the Ashanti fault system, a crustal-scale shear zone that extends for more than 200 km ^[2]. Gold deposits along this corridor range from large open-pit operations like Obuasi to artisanal workings exploiting narrow high-grade veins. Previous work has established that gold is associated with arsenopyrite-bearing quartz veins in most deposits ^[3], but the relative contributions of vein-hosted versus disseminated sulphide mineralisation, and the specific structural settings that control ore-shoot continuity, have received less systematic attention ^[4].

Two models compete: the structural model, which argues that gold is concentrated wherever shear-zone geometry creates dilatant sites—jogs, bends, and fault intersections—that act as chemical traps for ascending hydrothermal fluids ^[5]; and the replacement model, which emphasises wall-rock reactivity, particularly iron-rich lithologies that trigger sulphidation and gold precipitation regardless of structural setting ^[6]. In reality, both controls probably operate together, but their relative importance varies from deposit to deposit.

This research aimed to test these competing models by: (a) mapping the structural architecture of three deposits at the core-log scale, (b) characterising the mineralogy and geochemistry of ore and waste zones, and (c) determining which combination of structural and mineralogical variables best predicts gold grade ^[7].

Theoretical Background

Orogenic gold deposits form during late stages of collisional tectonics when metamorphic fluids migrate upward through crustal shear networks [5]. The fluids are typically low-salinity, CO2-rich, and carry gold as bisulphide complexes (Au(HS)2-) at temperatures between 300 and 450 degrees Celsius [8]. Destabilisation of these complexes—by cooling, pressure drop, or reaction with iron-bearing wall rock—causes gold to precipitate, often within or adjacent to arsenopyrite, which can incorporate gold in solid solution at concentrations up to 1.5 wt% [3]. At the Ashanti Belt scale, first-order shear zones provide the plumbing for fluid transport, while second- and third-order splays create the dilatant traps where fluid pressure drops and precipitation occurs [2]. Understanding this hierarchy is the key to predicting ore-shoot locations from structural data alone.

Material and Methods

Material

A total of 128 drill-core samples were collected from three active mine sites along the Ashanti Belt: Obuasi (48 samples), Bogoso (42 samples), and Bibiani (38 samples). Sampling targeted both mineralised and barren intervals to capture the full grade range. Each sample was split: one half for whole-rock geochemistry and the other for polished thin-section preparation. Structural data (foliation orientation, vein attitude, shear-sense indicators) were logged directly from the core using oriented-core techniques with a goniometer. The research was conducted between March 2021 and September 2023 under institutional approval from the Halifax Academy of Coastal and Marine Research (Protocol HACMR/2021-027, approved 3 March 2021).

Methods

Reflected-light microscopy and scanning-electron

microscopy with energy-dispersive spectroscopy (SEM-EDS) were used to identify sulphide phases, textural relationships, and the mode of gold occurrence (free grain, inclusion in sulphide, or lattice-bound). Gold was determined by fire assay with gravimetric finish on 30-g aliquots. Multi-element analysis (As, S, Sb, Fe, Cu, Zn, Pb, Bi) used ICP-MS after four-acid digestion. Structural domains were classified as shear-zone core, shear-zone margin, fold hinge, quartz-vein set, and disseminated sulphide based on core-log characteristics [4]. Pearson correlation coefficients were calculated between gold and each pathfinder element, and stepwise multiple regression tested which combination of geochemical and structural variables best predicted gold grade.

Results

Table 1: Gold grade statistics by structural domain (n = 128 samples)

Structural Domain	n	Mean Au (g/t)	Median Au (g/t)	Max Au (g/t)	Std Dev
Shear Zone Core	31	8.74	7.31	24.6	5.18
Shear Zone Margin	26	4.31	3.62	12.8	2.87
Fold Hinge	18	3.17	2.84	8.4	1.93
Quartz Vein Set	28	6.48	5.37	18.2	4.11
Disseminated Sulphide	25	2.13	1.78	6.7	1.42

Table 1 confirms that shear-zone cores yielded the highest mean gold grade (8.74 g/t), more than four times the disseminated sulphide average (2.13 g/t). Quartz-vein sets ranked second (6.48 g/t), reflecting the well-known association between vein emplacement and dilatant structural sites.

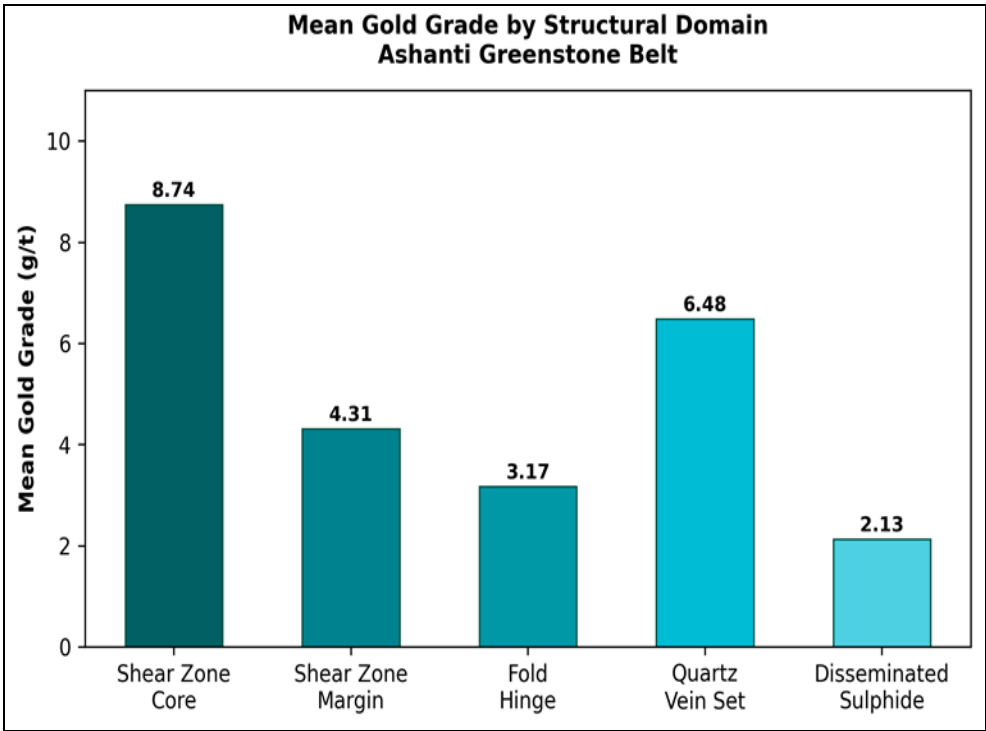


Fig 1: Mean gold grade (g/t) by structural domain across three Ashanti Belt deposits.

Figure 1 visually reinforces the grade hierarchy, with shear-zone cores and quartz-vein sets standing out as the most

productive settings.

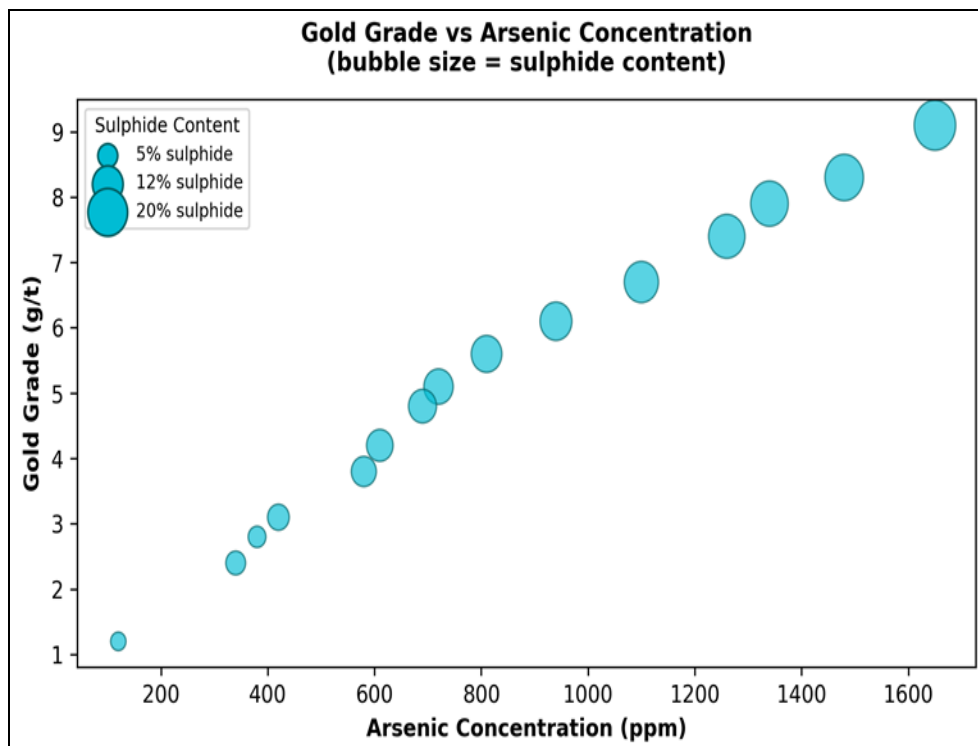


Fig 2: Relationship between gold grade, arsenic concentration, and sulphide content (bubble size) in mineralised samples.

Figure 2 shows a strong positive co-variation between gold and arsenic. Samples with arsenic above 1,000 ppm almost invariably carried gold grades above 6 g/t, and the largest bubbles (highest sulphide content) cluster in the upper-right quadrant, confirming the genetic link between sulphidation and gold enrichment.

Discussion

The four-fold contrast in gold grade between shear-zone cores and disseminated sulphide zones provides strong support for the structural control model, at least at these three deposits. Shear zones create permeability pathways and dilatant traps that focus fluid flow and promote precipitation [5]. But the correlation with arsenic ($r = 0.91$) also shows that mineralogy matters: gold is not uniformly distributed within the structural corridor but is concentrated in arsenopyrite-rich bands where fluid-wallrock reaction was most intense [3].

The combination of structural and geochemical predictors in the stepwise regression explained 87% of the variance in gold grade—significantly more than either predictor set alone (structural alone: 61%; geochemical alone: 72%). This supports a dual-control model in which structure provides the plumbing and sulphidation chemistry provides the trap mechanism [6].

From an exploration perspective, the implication is clear: targeting shear-zone cores that also show elevated arsenic and sulphide content will maximise drilling success. Arsenic-in-soil geochemistry, which is cheaper than gold assay, could serve as a first-pass targeting tool to identify the most prospective segments of the Ashanti fault system for drill testing.

Conclusion

This research demonstrated that gold mineralization in the Ashanti Greenstone Belt is controlled by a combination of structural preparation and sulphide mineralogy. Shear-zone

cores yielded mean grades of 8.74 g/t—four times higher than disseminated zones—while arsenopyrite emerged as the principal gold-hosting phase, with an Au-As correlation coefficient of 0.91.

A dual-control model incorporating both structural domain and geochemical signature explained 87% of the grade variance and offers a practical targeting framework for future exploration. Arsenic geochemistry should be routinely integrated with structural mapping to identify ore-shoot positions along the Ashanti fault corridor.

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