Regional deformation and mineral systems (gold focus)

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Birimian volcano-sedimentary belts with associated granitoids (2.25 to 1.96 Ga)
Late sedimentary sequence (2010-2000Ma)
1) **Ni deposits and Platinoid occurrences** are along Archean Craton Margin and ultramafic intrusions

2) **Base metal and copper-gold systems.** The Boromo Belt in Burkina Faso has VMS deposits (Zn-rich Perkoa deposit) and Cu-Au porphyry systems with calc-alkaline volcanic rocks (Gaoua).

The restricted nature of the distribution of these systems compared to the gold-only systems, is inferred to reflect the distinct tectonic settings that these deposits form in.
Major focus on gold-only systems on WAXI2 – very diverse distribution
Projets en Afrique

- **Mana** ~ 2 million ounces, Burkina Faso
- **Morila**, Mali (~7 million ounce)
- **Syama**, Mali (~5 million ounce)
- **Komana**, Mali
- **Siguiri**, Guinea (~7 million ounce)
- **Bogoso**, Ghana (~5 million ounces)
- **Obuasi**, Ghana (~50 million ounces)
- **Sadiola**, Mali (~5 million ounce)
- **Kiniero**, Guinea (~1 million ounces)
- **Bogoso**, Ghana (~5 million ounces)
Gold deposit host rocks (2.2-2.1 Ga)

Host rock types range from;

• carbonate-hosted (Sadiola)
• sediment-hosted (Siguiri, Obuasi)
• sediment and granitoid hosted (Kalana)
• mafic intrusive hosted (e.g., Syama)
• mafic volcanic hosted (e.g. Kiniero)
• granitoid hosted (e.g. Banfora, Subika)
• placer deposits in quartz-pebble conglomerates (Tarkwa).
Tarkwa Lode (late stage basin)

Sadiola (carbonate)

Obuasi (graphitic sediments)

West Banfora (granitoid)

Pampe (mafic dykes)
Deposit styles/ models

• Intrusion-related (e.g. ~8 Moz Morila deposit; McFarlane et al., 2011)
• Classic fault-valve orogenic gold models (e.g. > 5 Moz Damang deposit; Tunks et al., 2004)
• Paleoplacer systems (e.g. >28 Moz Tarkwa deposit; Pigois et al. 2003)
• Cryptic early poly-deformed deposits (e.g., ~5 Moz Wassa deposit; Bourassa, 2003).
• Ductile shear zones (Wassa), fault-vein arrays (Kalana, Damang), and Low-T brittle high level breccias (Syama).
Syama: low –T breccia (mafic intrusive)

Damang: low angle veins

Wassa: folded ductile shear zone (mafic volc.)

Morila: high T with partial melts
Kinematics

• Multiple phases of gold mineralization with different kinematics and alteration occurred, in some cases within the same belt.

• Regionally a dominant late-stage gold D4 event at ca. 2100 - 2070 Ma (Feybesse et al., 2006), which is commonly associated with NW-SE shortening and high arsenic e.g., Obuasi (Allibone et al., 2002).

• Also later stage D5 brittle stage (Syama and Damang).

• World class Tarkwa Formation Paleoplacers in the Ashanti belt predate the D4 gold event – this requires an older gold event to have acted as a source.

• Evidence for early D1/D2 gold systems that pre-date Tarkwa deposition groups deposits is strong (in comparison for example to early gold models in the Yilgarn Australian Archean orogenic gold deposits = MAJOR DIFFERENCE in the systems).
Architectural Controls

- Deposits formed at different geological times and have markedly host rocks and different deposit styles defined by observable structural, metamorphic and alteration.

- At the belt and regional scale architectural controls appear to be a key control on the gold deposit locations

- This could be an effective targeting tool within a prospective greenstone belt

- Similar observations made for the Western Australian Goldfields
Major variations between individual deposits. Belt scale architectural controls appear to be a control on deposit location.

Intersections, ENE- & N-trending architecture (dykes map these)
Cryptic cross structures, linked to along strike facies changes and mineralisation
MINERALISATION - STRUCTURAL TIMING
(SOUTHERN MALI AND GUINEA)

Four economically significant stages of mineralisation have been identified;

1) Possible early D2 mineralisation at the Morila deposit with a strong late-stage gold over print linked to ME3 magmatism

2) Regionally extensive D4 associated gold lodes related to NW-SE shortening (commonly with quartz and arsenic; e.g. Kalana and Tabakoroni),

3) Steep-dipping gold-bearing quartz veins linked to post-D4 extensional collapse e.g. Kalana and Siguiri (=major artinalis sites)

4) Late-stage D5 high-crustal level low-T breccias associated with ankerite and pyrite e.g. Syama, Banfora.
Ashanti Belt (Ghana). Major deformation events and phases of gold

- Poorly defined early events
- Early D1 gold at Wassa – this is pre-deposition of Tarkwa unit
- Deposition of Tarkwa units and paleoplacers
- D2 = Early bedding parallel fabrics (Obuasi, Bogoso)
- Major D3 NW-SE shortening linked to regional folding of all sedimentary sequences and shear development
- Gold related to horizontal stretching and NW-SE shortening (defined as late D3, could mark switch to D4)
- Regional D4 event linked to a major phase of gold mineralisation with a regional cross cutting D4 crenulation cleavages, sinistral slip linked to NNW-SSE shortening (=D3, D4 and D5 of Allibone et al., 2002)
- D5 NE-SW to ENE-WSW shortening linked to low angle veins and associated gold mineralisation within the Tarkwa units at Damang
- Early N-trending and ENE-trending architecture is a probable control on deposits (combined with fault intersections)
**Ashanti Belt – linked to WAXI2 event history**

Local events versus WAXI2 event history

D1 and D2 poorly constrained
Wassa (Early Gold, interpreted D1 with overprints)
• Texturally early gold
• Grade control data suggests lodes are folded
• Re-Os ages of sulphides from the Wassa deposit produced two ages $2164 \pm 22$ Ma and $2054 \pm 11$ Ma (Le Mignot et al., in review).
Tarkwa Unit Paleoplacer (Tarkwa)

Paleoplacer with hydrothermal overprint (Damang)

2.48 g/t
D3 graphitic shears (Obuasi and Bogoso)

Bogoso

Work by A. Allibone

Obuasi

Sediment
The Anyankyerim Deposit has metaturbidites and mineralised granitic sills (2105 ± 2Ma; Oberthur et al., 1998)
Low angle lineation / principal stretch direction
Gold-bearing disseminated arsenopyrite at Obuasi is late D3 to early in the D4 event (pressure shadows folded by D4 cleavages). Junner 1932 noted same relationships.
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Late D3 = NE-SW directed stretching and NW-SE shortening
Linked to gold (overprinted by D4 cleavages)
1. Sills and dykes intruded (ca. 2100 Ma)

2. Boudinage and veining in boudin necks

3. Mineralised quartz veins with pyrite and ankerite

4. NW-SE to NNW-SSE compression

5. D4_{Anky} low angle quartz vein emplacement

Late Regional D3

Regional D4

NW-SE to NNW-SSE compression
Obuasi - Major gold control from D4 cleavages (Allibone et al., 2002)
D4 gold mineralisation (gabbro and dyke hosted) NW-SE shortening

Main trend (red)
Splay Fault (black)
D5 gold mineralisation NE-SW shortening

Main Damang Pit

West African Metallogenesis meeting, Dakar, September, 2015
D5 Damang deposit (& late D5 veins at Anyankyerim)

Regional low angle D5 veins
Local D4 in many areas
In the Ashanti Belt there is a strong late D4 NW-SE shortening event linked to Au. In this belt, and across the Birimian, it is more complex in terms of the timing of the gold, and not all world class gold deposits fit into this event.
SUMMARY

• Gold deposits have a broad geographic extent and structural styles ranging from ductile shear zones at High-T (Morila), fault-vein arrays (Kalana, Damang), to brittle high level low-T breccias (Syama).

• Host rock types for the gold deposits range from sediment-hosted (Siguiri), sediment and granitoid hosted (Kalana), volcanic and mafic intrusive hosted (Syama)

• Multiple phases of gold mineralization with different kinematics and alteration occurred

• Some phases of gold predate the deposition of the Tarkwa units (Wassa and interpretation for Morila). These deposits could be potential analogues of the source for the world-class palaeo-placer deposits occurring within the Tarkwa Formation in Ghana.

• There is a dominant D4 gold event, commonly associated with high arsenic mineralization, with consistent kinematics linked to NW-SE shortening.

• Architectural controls on all systems, and the controls on the localisation of early gold deposits (e.g. Wassa), should be a focus area of research.