The potential for gold in Liberia
Liberia—a major under-explored West African gold terrane:

- Recent exploration success and new mine development have led to a considerable increase in activity.
- 90 per cent of Liberia is underlain by the Archean and Birimian, two of the most productive gold-bearing terranes globally.
- These rocks host multi-million ounce gold deposits in neighbouring countries.
- Liberia has not been systematically explored using modern techniques and deposit models, so the potential for new discoveries is great.

The geology of Liberia

Liberia is located within the Man Shield, part of the West African Craton, which comprises two major areas of Archean and Paleoproterozoic rocks. Liberia was mapped during the 1970s in a joint programme between the Liberia Geological Survey (LGS) and the United States Geological Survey (USGS). Aeromagnetic and aeroradiometric maps for the entire country, supported by field checking, allowed the bedrock geology and main tectonic divisions of Liberia to be defined.

Liberian age (2.5–3.0 Ga) Archean basement, extending across central and western Liberia, is characterised by a granite-greenstone association.
dominated by granitoid gneisses and migmatites, which are infolded with supracrustal metavolcanic and metasedimentary rocks and intruded by a younger igneous complex. The supracrustal rocks form discontinuous narrow, elongate 'schist belts'. The metamorphic grade is generally amphibolite facies with greenschist facies dominating the schist belts.

The boundary between the Archean and Paleoproterozoic age rocks (Eburnean age province, 1.9–2.3 Ga) is not well defined in eastern Liberia, but is generally considered to lie along the north-east-trending Cestos Shear Zone. The south-eastern part of the Eburnean age province in Liberia, extending west from Côte d’Ivoire to Greenville, consists of tightly folded paragneiss, migmatite and amphibolite. The north-western part of the province, to the north of Greenville, has similar lithologies and geophysical characteristics, but younger isotopic ages.

An extensive Paleoproterozoic volcano-sedimentary sequence, the Birimian Supergroup, borders the Archean basement of the Man Craton along its northern and eastern margins. The supracrustal rocks are surrounded by a regionally extensive granitoid complex. Although the genetic relationship between the Birimian sequence elsewhere in West Africa and the Eburnean age province of Liberia is unclear, they are generally considered to be equivalent.

Pan African–age rocks (c. 550 Ma) underlie an elongate, fault-bounded zone along much of Liberia’s coastline. They comprise metasedimentary and mafic metaigneous rocks containing granitic bodies and subordinate noritic intrusions. Phanerozoic rocks in Liberia include extensive north-west-trending Jurassic-age dolerite dykes, minor Paleozoic and Cretaceous sandstones and unconsolidated Quaternary deposits.

Multiple phases of deformation are present in the Precambrian rocks. The structural trend of the rocks in the Liberian and Eburnean age provinces is principally north-east, whereas that of the Pan African province is mainly north-west. A number of major north-east-trending faults in eastern Liberia are extensions of regional structures, which extend into Côte d’Ivoire, and include the economically important Cestos, Dugbe, Dube and Juazohn shear zones. The Lofa River Shear Zone in north-west Liberia also trends north-east. The north-west-trending Todi Shear Zone marks the boundary of the Pan African province and comprises a series of south-west-dipping faults associated with intense zones of mylonite.

Gold in Liberia

There is a long history of artisanal gold mining in Liberia from alluvial placers with production peaking at more than 30,000 ounces per annum in the 1940s. Between 2008 and 2012 annual production is estimated at about 20,000 ounces per annum (BGS, 2015).

The cratonic geological environment of Liberia is favourable for two main types of gold deposit:

i) greenstone-hosted quartz-carbonate vein deposits (a subtype of lode gold deposits) in a wide variety of host rocks;

ii) alluvial placer deposits.

Nearly 600 gold occurrences have been recorded in Liberia, with gold placer deposits accounting for almost 80 per cent of the total.
Placer gold deposits

Deep and intense weathering since the Pleistocene, and persistent erosion in areas of moderate to low relief, coupled with clay bottoms to most of the gravel deposits, favour the development of gold placers across Liberia although most are found in the eastern and western parts of the country. The deposits worked by artisanal miners are generally less than two metres thick, and are narrow and discontinuous in form. The gold grains have rounded edges and are moderately coarse in size, with nuggets widely reported.

A number of ‘gold belts’ have been defined based on the distribution of alluvial placer deposits:

- Bea Mountain
- Bopolu-Wuesua-Tawalata
- Masawo-Zolowo-Zorzor
- Mano River-Wologizi Range
- St. John River-Kokoya
- Cestos River
- Putu Range-Zwedru
- Bukon Jedeh

Each of these includes a large number of alluvial placer deposits some of which have been worked in the past and others where significant resources remain. However, it is generally considered that major placers amenable to large-scale modern mining methods are unlikely to be found in Liberia. The widespread occurrence of placer deposits suggests significant potential for bedrock-hosted gold mineralisation and provides useful guidance on exploration targeting.

Bedrock gold deposits

Bedrock gold deposits in Archean and Proterozoic terranes in West Africa are highly varied in size and form but typically consist of mineralised shear zones and structurally-controlled quartz veins, and are comparable with granite-greenstone-hosted lode-gold mineralisation globally.

Archean lode-gold deposits

Lode gold deposits in Archean rocks in Liberia are found in a wide variety of greenstone-belt lithologies with metamorphic grade ranging from lower greenschist to upper amphibolite facies. The mineralisation, which may comprise quartz veins, breccia zones, stringers and disseminations, typically extends over widths of 10-20 metres and may have a strike extent of more than a kilometre. Structure exerts strong control on its distribution with north-east-trending zones of intense shearing being particularly important. Other favourable sites include zones of polyphase deformation, fold limbs and closures, and competency contrasts such as sheared lithological contacts. The mineralisation comprises free gold closely associated with a range of silicates, including quartz, tourmaline, chlorite and sericite, and various sulfide minerals.

The gold-bearing mineralisation may be associated with local development of a range of alteration minerals including, most commonly, chlorite, carbonate and sericite. In some deposits, dependent on host rock lithology, the alteration assemblages may include phlogopite, talc,
magnetite, hematite, iron sulfide, tourmaline and tremolite. A range of metals may be enriched in the gold-bearing ores including arsenic, tungsten, cadmium, copper, lead and zinc.

Perhaps the best known and economically most important gold occurrences in the Archean greenstone belts are found in north-west Liberia associated with a series of major north-east-trending structural lineaments, principally shear zones. New Liberty is a shear zone-hosted gold deposit in Archean age rocks with a greenstone belt affinity. It is a fully financed project with planned annual production of 120,000 ounces of gold which began in 2015. Further details are given in Deposit Profile 1. Numerous additional major gold occurrences occur along a structural corridor extending north-east of New Liberty. Prominent examples include Weaju and Ndablama where exploration continues and significant gold resources have been identified. At Ndablama, in an area of established alluvial gold mining, gold mineralisation is hosted in sheared ultramafic and mafic rocks intercalated in a gneiss sequence above a buried granite body. Gold is frequently localised along sheared contacts between the ultramafic and mafic units that are intruded by granitic dykes and breccias. Phlogopite, tremolite, chlorite and talc alteration is associated with the mineralisation. A mineral resource (indicated + inferred) containing 901,000 ounces of gold at a grade of 1.6 g/t Au was reported at Ndablama in December 2014.

Exploration in the Kpo Mountains area of Gbarpolu County has identified gold-bearing quartz veins. Mineralisation is thought to be related to sheared lithological contacts between granite, granitic gneiss and supracrustal rocks, consisting of BIF, schist and amphibolite. To the north of the Kpo Range gold-bearing veins, hosted in granite and granitic gneiss, occur in the Lucky Hill (Gblita) area. Mineralisation appears to be controlled by the lithological contact between granite and granitic gneiss.

Gold mineralisation comprising brecciated quartz stockworks in strongly sheared zones has been located in the Mandingo Hill area in Bomi County. A number of structurally controlled, quartz-sulfide-bearing gold occurrences occur in the Mount Coffee area of the Todi Shear Zone. Further east along the shear zone at Kle Kle several broad zones of gold mineralisation have been defined.

Quartz vein-hosted and disseminated gold mineralisation occurs in strongly sheared schists in the Toto Mountain Range area in Bong County. In the south of Bong County a mineral resource (indicated) containing 210,000 ounces of gold at a grade of 3.5 g/t Au is reported at Kokoya. The mineralisation is structurally controlled and hosted in a package of strongly deformed amphibolites and gneisses.

Proterozoic lode-gold deposits

Most West African gold production has been derived from Birimian-age greenstone belt rocks rather than from the Archean.

Little systematic modern exploration has been undertaken over the Birimian terrane in south-east Liberia and the geology has not been studied in detail. However, as in the Archean terrane, alluvial gold occurrences are numerous and widespread and significant mineralisation in bedrock is known at several localities. Host rock lithologies are varied but commonly include metavolcanic and metasedimentary rocks, mafic and granitic intrusives, pegmatites and sulfide-rich schists and gneisses. The mineralisation is commonly located at the host rock contact with banded iron formation (BIF). The mineralised bodies have variable morphology, ranging from irregular

Deposit Profile 1: New Liberty, Grand Cape Mount County, north-west Liberia

Deposit style: Archean shear zone-hosted gold.
Local geology: footwall and hanging wall gneiss and banded migmatites, containing greenschist-amphibolite facies ultramafic rocks that host the gold.
Deposit geology: structurally-controlled mineralisation in a 100 metre-wide, steeply-dipping ultramafic unit. Mineralisation is 10–20 metres wide, strike length 2 kilometres.
Mineralogy and alteration: free gold associated with silicates and sulfides (pyrrhotite, arsenopyrite, gersdorffite). Weak silicification, magnetite destruction and phlogopite alteration.
Mineral reserve: 8.5 million tonnes @ 3.4 g/t Au.
Mining: Continuity of mineralisation to 500 metres proven by drilling. Open pit to 220 metres planned.
Exploration: mineralisation associated with enhanced S, As and W and enrichment in Na, K, Rb and Ba along marginal zones; strong magnetic and induced polarisation responses.
sheets, to quartz-carbonate sulfide-bearing veins, disseminated sulfides and sulfide stringer veins. As in the Archean terrane geological structure is a dominant control on the location of gold mineralisation. Particularly favourable sites include second-order structures to regional shear zones, structural intersections, lithological contacts, grain-size variations within sedimentary packages and zones of polyphase deformation. The gold occurs as free grains commonly closely associated with sulfide phases, chiefly pyrite, arsenopyrite and pyrrhotite. Hydrothermal alteration is present in some deposits, commonly with attendant enrichment in arsenic, bismuth and silver.

The most important bedrock gold deposits in this terrane are spatially associated with major regional shear zones trending either north-east or east-north-east. Numerous gold occurrences (e.g. Jueh-Bukon, Numon South) have been identified in the environs of the Cestos Shear Zone, which lies along the contact between Archean and Proterozoic rocks and represents a near-vertical, crustal-scale structure that has been compared with the Ashanti Gold Belt in Ghana. The Ity gold mine in Côte d’Ivoire is located on the north-eastern extension of this shear corridor.

The Juazohn Shear Zone is another highly prospective target on account of known bedrock occurrences, extensive alluvial deposits and gold geochemical anomalies. BIF-associated gold deposits are the principal target in the area. High grade mineralisation has been reported at several locations including Zia in the north, Zwedru to the west and in the Putu Range area which straddles the Juazohn Shear Zone.

The regional Dugbe Shear Zone in south-east Liberia has been the focus of increasing gold exploration in recent years. To date the most significant discoveries are located at Dugbe 1 about 40 kilometres east of Greenville in Sinoe County. These foliation-parallel disseminated gold deposits are hosted in high-grade, migmatitic rocks. Further details are given in Deposit Profile 2. Approximately 12 kilometres to the south-east drilling has intersected significant high-grade gold mineralisation at Bukon Jedeh. The intrusive contact with a granite is a favoured site for high grade gold in this area. Along strike to the west of the Dugbe 1 Project gold mineralisation has been identified in the Sinoe area, which is characterised by biotite and garnet-biotite schists, intruded by sulfide-bearing quartz-feldspar-mica pegmatites and mafic and granitic intrusives. The highest gold concentrations appear to be associated with pegmatitic zones.

**Potential for new discoveries**

The wide distribution of placer gold deposits across Liberia indicates the potential for new major bedrock gold discoveries. Under-explored areas of alluvial mining activity are priority targets for future exploration.
The distribution of BIF, considered to be the source of much of the placer gold in the Archean of West Africa, is relatively well known in Liberia on account of the extensive exploration that has taken place for iron and the availability of national aeromagnetic data. The relationship between bedrock gold and BIF in Liberia is illustrated by the Innis prospect to the north of the Cestos Shear Zone, where gold is associated with disseminated and vein-hosted sulfides hosted by sericite-altered gneiss, BIF and garnet schist. Other areas with extensive BIF, coinciding with major structural corridors, are highly prospective. Targets of this type associated with alluvial gold occurrences are located in the Nimba, Putu and Wolofizgi ranges.

In north-west Liberia the under-explored north-east extension of the Archean-granite-greenstone terrane, bounded by the Lofa and Yambesei shear corridors, is a priority target for gold exploration, owing to the favourable geology, structure and alluvial placer deposits.

Other areas that merit further investigation include: the southern end of the Todi Shear Zone in the River Cess area where limited sampling has revealed elevated gold concentrations in the laterite; the northern extremities of the Dugbe Shear Zone and the Dube Shear Zone, where anomalous gold values in stream sediments have been reported; and the western end of the Dube Shear Zone in the Jolodah Village area of Grand Kru County where alluvial gold is widespread, although the bedrock source has not been identified.

Selected references

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