The potential for iron ore in Liberia
Iron ore in West Africa

West Africa has numerous deposits and major resources of iron ore. Currently it accounts for 15 per cent of African production with most mines located in supracrustal rocks in Sierra Leone, Guinea and Liberia (BGS, 2015). Various types of iron ore deposit have been recognised. The most important and widespread deposits are ‘banded iron formations’ (BIFs), most of which belong to a Lower Proterozoic supracrustal sequence that rests unconformably on crystalline Archean basement of the Man Shield, the southern part of the West African craton that underlies much of the region.
These BIFs have been recrystallized under regional greenschist to amphibolite grade to form itabirites which comprise alternating bands of quartz, magnetite and/or hematite mineralisation. Perhaps most notable is the world-class Simandou BIF deposit in south-east Guinea which has reserves of over 1.8 billion tonnes grading 65.5% Fe and planned production of 100 million tonnes per annum for a period of more than 40 years – this is the sixth largest iron ore deposit in the world. In Sierra Leone the Tonkolili (Archean BIF) and Marampa (Neo-proterozoic specularite) mines opened in 2011, and ramped up to produce almost 12 million tonnes of iron ore in 2013 (BGS, 2015). In western Côte d’Ivoire the Mount Tortro and Mount Klahoyo BIF deposits are being developed.

The Nimba Range has BIF resources in the Mount Nimba deposit in Guinea and in the Mount Nimba and Mount Gao deposits in Côte d’Ivoire. In Liberia, the Nimba Range deposits, worked until the 1990s, are now exhausted.

Although current production from the region is small in global terms, it should be noted that mining re-commenced as recently as 2011 in both Sierra Leone and Liberia. There is little doubt that in the longer term, as global demand recovers and with improved security and political stability in the region, West Africa will become an increasingly important supplier of iron ore.

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 Liberian Geological Survey (LGS) and the United States Geological Survey (USGS). Aeromagnetic and aeroradiometric maps for the entire country, supported by field checking, were the principal source of information used to interpret the geology.

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. These are infolded with supracrustal metavolcanic and metasedimentary rocks and intruded by a younger igneous complex. 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. An extensive Paleoproterozoic volcano-sedimentary sequence, the Birimian Supergroup, is found to the east of the Archean basement. The supracrustal rocks are surrounded by a regionally extensive granitoid complex.

In Liberia, the iron ore formations are generally of the itabirite type – metamorphosed banded iron formations. The three major metamorphic events recognised in Liberia, the 2.5–3.0 Ga Liberian event, the 1.9–2.3 Ga Eburnean event and the Pan African Orogeny (c. 550 Ma) resulted in the metamorphism of the BIFs to itabirites (Kromah, 1974). Supergene processes played an important role in the development of most high grade iron ores, notably at Goe, Mano River and Wolofizi. These processes led to iron enrichment in a cap-rock, known as ‘canga’, which forms a blanket over the current or paleo-surfaces of the itabirite. Canga refers to a breccia of weathered BIF and iron ore clasts that are cemented by secondary Fe(III) oxides and hydroxides and are relatively resistant to weathering processes (Harder, 1914; Schuster et al., 2012).

Some minor components of iron ore, such as phosphorus, aluminium and manganese, may impact on the quality of the steel produced. In Liberia, limited data suggest that the phosphorus content of some deposits is generally in the range of 0.05–0.10% which is slightly higher than ideal (<0.01% P) (Williams, 1986). However, as the iron ore deposits are generally of low- to medium-grade and suitable for blending, the phosphorus content can be readily managed to achieve acceptable concentrations.

Iron ore resources in Liberia

Numerous iron ore occurrences and deposits are known in Liberia with most being BIF type (see map). Of the eight major deposits, six are located within the Liberian age Archean basement in central and western Liberia while one is found in the Eburnean terrane in the east and another in the Pan African coastal belt. Historically Liberia was a major global producer of iron ore, being the 7th largest in the world in 1980. Thereafter production levels declined until 1992 when the intensity of the civil war led to the closure of operations on the Nimba deposit at Yekepa. After the cessation of hostilities and the establishment of a democratically-elected government in 2006 there was revival of commercial interest in Liberia’s iron ore resources. China Union Investment
Bong Mines Company Ltd. (commonly known as China Union) and ArcelorMittal were the first companies to start production. Production of ‘direct shipping ore’ (DSO) commenced in 2011 from the first of three deposits at Yekepa (Mount Tokadeh, Mount Gangra and Mount Yuelliton) in the ‘Western Range Project’ (WRP) operated by ArcelorMittal. At present iron ore is mined from two deposits, Mount Tokadeh in the WRP, which produced 4.9 million tonnes in 2014 (ArcelorMittal, 2015), and the Bong mine, operated by China Union, which recorded its first production of 50,000 tonnes in early 2014. In 2013, Liberia was ranked the 24th largest producer of iron ore in the world after just three years of production (BGS, 2015).

Investment in the iron ore sector has led to further developments of infrastructure such as the refurbishment of the Buchanan to Yekepa railroad and the development of a new iron ore berth at the Buchanan port. Exploration activity for iron ore in Liberia was until recently at a high level, with numerous exploration licences being held over the most prospective belts of supracrustal rocks that form many of the mountain ranges in the country. However, the Ebola crisis in 2014, followed by low iron ore prices in 2015, led to a reduction in activity.

Iron ore deposits in Liberia

The Nimba Range and deposits at Yekepa

The Nimba Range extends over 30 kilometres along the border zone of Guinea, Côte d’Ivoire and Liberia. Historically iron ore has been exploited from both the Liberian and the Guinean sectors. In Liberia, the main Nimba ore body, now mostly mined out, is located in one of two parallel bands of Archean BIF with a north-east strike. Production commenced on the Nimba deposit in 1963 and peaked at 12 million tons in 1974 but subsequently declined due to market conditions. Production started at Mount Tokadeh in 1985 to extend the life of the Nimba mine but operations ceased in 1992 with the intensification of the civil war.

The ArcelorMittal-owned mine at Yekepa is located about five kilometres west of the now exhausted Nimba Range deposit. Production from the Mount Tokadeh deposit at Yekepa, part of the Western Range Project, is from high-grade oxidised ore, with an average iron content of 60–62%. This ore only requires crushing and screening to make it suitable for export. Total ore reserves at Yekepa are 501 million tonnes at 48.3% Fe (ArcelorMittal, 2015).

Bong

The Bong Mine is located about 110 kilometres north-east of Monrovia and occurs at the western end of the north-west-trending Bong Range. The mine was operated by the Bong Mining Company between 1965 and 1990 when 158 million tons of medium to high grade iron ore were extracted. It is currently being exploited by China Union with first ore exported in 2014. Further exploration has identified additional resources at Goma to the east of the Bong deposit.

The Western Cluster (Mano River, Bomi Hills and Bea Mountain)

Historically a major iron ore producing region, these deposits in western Liberia, now referred to as the Western Cluster, are being developed by...
Vedanta Resources through its subsidiary Western Cluster Ltd. Early production in the 1950s took place first at Bomi Hills and subsequently at Mano River. At the same time, the railway between Monrovia and the Bomi Hills mine was constructed and the first port at Monrovia was established. The combined effects of the 1970s oil shock and the subsequent period of civil unrest led to the cessation of mining at the Mano River mines and exploration at the Bea Mountain deposit.

Ongoing exploration is focussed on the three deposits that constitute the Western Cluster and the company has acquired right of access to the old rail corridor to Monrovia port and two piers at the port. Drilling has been undertaken at all three deposits and in the licence areas surrounding them. Generally the itabirites of the Western Cluster deposits are weathered at surface to produce high grade ore from the canga above an unweathered magnetite-bearing primary ore. At Mano River and Bomi Hills this weathered cap has been exploited by previous mining ventures, yet much of it remains at Mano River. Bea Mountain has never been worked for iron ore. Vedanta Resources is currently evaluating its plans for the transport and export of iron ore from the Western Cluster deposits.

The Mano River deposit, located about 140 kilometres north of Monrovia, is the northernmost of the deposits in the Western Cluster and has an inferred resource of 95 million tonnes at 32.9% Fe (Vedanta Resources, 2014). Current exploration comprises geological mapping, aeromagnetic surveys and diamond drilling.

The Bomi Hills mine, located 50 kilometres north of Monrovia, was a historic producer of high-grade DSO magnetite in addition to magnetite concentrate beneficiated from itabirite. Currently exploration is ongoing in the area surrounding the Bomi Hills mine. A SAMREC resource of 291 million tonnes at 33.8% Fe, with probable reserves of 141.65 million tonnes at 35.67% Fe, has been reported in addition to the potential resources in fine tailings from previous operations that may be reworked for iron (Vedanta Resources, 2014).

The Bea Mountain deposit, approximately 100 kilometres north of Monrovia, has been explored by Vedanta Resources in recent years. The inferred resource, greater than 500 million tonnes at 33.2% Fe, has not yet been exploited (Vedanta Resources, 2014).

Wologizi Range

The large, low grade deposit in the Wologizi Range has a long history of exploration but is yet to be worked on an industrial scale. The Wologizi Range itself, located in north-western Liberia approximately 200 kilometres north-north-east of Monrovia, extends over a total length of about 50 kilometres and includes about 23 kilometres of BIF (White, 1973). It has speculative resources of 1.271 billion tonnes at 30–45% Fe (Williams, 1986).

Putu

The Putu deposit includes 12 kilometres of BIF that form a series of mountains, including Mount Gedah, Mount Chea and Mount Taeley. These are located approximately 120 kilometres north-east of Greenville in eastern Liberia and, unusually, they occur in rocks of Eburnean age rather than Archean. The deposit is currently being evaluated by Sevestral Resources and has a SAMREC reserve of 102 million tonnes at 59.3% Fe, with low contents of phosphorus and aluminium. A much
larger resource of lower grade ore is also present at Putu.

**Mofe Creek**

The Mofe Creek project is located within one of Liberia’s historic iron ore mining districts in western Liberia, approximately 65 kilometres from Monrovia and 10 kilometres along strike to the west of the Bomi Hills deposit. It is currently being explored by Tawana Resources and has a maiden JORC resource estimate of 61.9 million tonnes at 33% Fe, including an indicated mineral resource of 16.2 million tonnes at 35.4% Fe. The deposit is characterised by coarse grained itabirite, with both hematite and magnetite mineralisation present.

**The Goe Fantro Range**

The Goe Range (or Goe Fantro) is located approximately 60 kilometres south-east of Monrovia in the coastal Pan African belt of supracrustal rocks. The deposit is also unusual in that it has a north-west strike while all other iron ore deposits in Liberia have a north-east trend. Exploration in the Goe Fantro area was first undertaken in the late 1950s, prior to the discovery and development of the Nimba deposits. The Liberian American-Swedish Mining Company (LAMCO) identified a resource of 40 million tons in two deposits at 55–60% Fe. Two iron-rich bands have been identified, one silicate rich and the other oxide rich. However, the deposit is known to have elevated levels of some impurities such as phosphorus (0.27%), aluminium and manganese. Supergene enrichment has been important in upgrading the iron content at Goe Fantro and a canga cap is widely developed. The Goe Fantro deposit is currently under license to Cavalla Resources.

**The Buchanan Fines**

This is a ‘deposit’ of secondary material of fine grain size, located adjacent to Buchanan port and derived from the processing of iron ores originating from the Nimba Range mine in the 1970s and 1980s. The tailings from this process constitute a small but potentially easily-exploited JORC-compliant resource, which is estimated at 11 million tonnes (measured) of hematite fines with a grade of 45% Fe (Jonah Capital, 2013). Production is planned to start in 2016, with an expected mine life of between five and six years.

**Other occurrences**

Additional iron ore occurrences of potential economic importance are widespread, especially in the Archean terrane. These are located in:
the Kpo Range in western Liberia. Exploration has been undertaken in recent years but it is currently not deemed prospective.

- the Toto Range in western Liberia which has been explored in recent years by BHP Billiton and by a joint venture between Cavalla Resources and AngloAmerican. It is currently owned by Cavalla Resources.

- the Central Liberian Plateau, where the Timbo and St John River South (SJRS) occurrences have been explored by BHP Billiton but are now owned by Cavalla Resources.

- the Kitoma area in north-east Liberia, which was first explored during the 1960s. BHP Billiton carried out some exploration here up to 2014 but these licenses are now held by Cavalla Resources.

- Webo Hill in eastern Liberia, hosted in Eburnean-age metasedimentary rocks. This is considered uneconomic on account of its reported high phosphorus content (c. 0.45%), although high iron grades are locally present in laterite and canga (Williams, 1986).

There are also many other occurrences previously recorded by the USGS and the LGS for which no additional information exists.

**Potential for new discoveries**

Although considerable work has been carried out over a long period to assess the iron ore resources of Liberia, large tracts of the country are poorly known in detail and have not been systematically explored using modern techniques. The national digital geological and aeromagnetic datasets, available from the Liberian Geological Survey, provide an excellent basis for identification of areas prospective for new iron ore deposits. Certain under-explored areas are of particular interest on account of the known occurrence of extensive banded iron formation such as the Putu Mountain Range in the east of the country. Many areas, such as the Wologizi Range, the Putu Range, the Toto Range, Webo Hill and the Central Liberian Plateau, would benefit from systematic mapping, sampling and evaluation of targets with modern exploration techniques, backed up by high-resolution airborne geophysical surveys.

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