Investing in the minerals industry in Liberia
Introduction

The Republic of Liberia is located in West Africa, bordered by Sierra Leone, Guinea, Côte d’Ivoire and to the south-west by the Atlantic Ocean (Figure 1). With a land area of about 111 000 km² and a population of nearly 4.1 million much of Liberia is sparsely populated comprising rolling plateaux and low mountains away from a narrow flat coastal plain. The climate is typically tropical, hot and humid at all times, with most rain falling in the summer months. The population comprises a large mix of ethnic groups, although English is the official national language. Monrovia is the capital city with a population of approximately 750 000. There are several other important settlements in the country (Figure 1).

Liberia has a total of 29 airports of which two have paved runways. It has a road network amounting to 10 600 kilometres and 429 kilometres of railway. It has two major seaports, located in Monrovia and Buchanan, with smaller ones at Greenville and Harper. Electricity is generated almost exclusively from imported fossil fuels, although there is significant potential for major hydroelectricity generation in several areas.

Following 14 years of war and civil unrest between 1989 and 2003, democratic elections were held in late 2005. The installation of a democratically-elected government, backed up by the presence of a United Nations peacekeeping force, has served to reinforce investor confidence in Liberia. Furthermore, Liberia is richly endowed with natural resources, including minerals, water and forests, and has a climate favourable to agriculture. Since the cessation of hostilities the country has made strenuous efforts to strengthen its mineral and agricultural industries, mostly timber and rubber.

Mineral resources, especially iron ore, have in the past been of great importance to the Liberian economy. However, during the war, all the mines were closed and much infrastructure destroyed. Following cessation of civil unrest and buoyed by generally rising commodity prices from around 2000 onwards, there was a significant revival of interest in exploration and mining. Most growth occurred in the iron ore sector, although there has also been considerable interest in gold and, to a lesser extent, in diamonds. However, in 2014 the combination of falling global commodity prices and the outbreak of the Ebola Virus Disease (EVD) had a serious impact on the Liberian economy and foreign investment declined significantly. Liberia’s main trading partners in 2014 were North America, Asia and Europe; intra-ECOWAS (Economic Community of West African States) trade was seriously affected by EVD, falling by more than 40% from 5.7% of total trade in 2013. Liberia’s exports in 2014 totalled about US$561 million and were dominated by iron ore (c. 70 per cent of total) and rubber (17.5 per cent).

Investing in the minerals industry in Liberia:

▪ Extensive Archean and Proterozoic terranes highly prospective for many metals and industrial minerals, but detailed geology poorly known.
▪ Gold, iron ore and diamonds widespread, with new mines opened since 2013 and other projects in the pipeline.
▪ Known potentially economic targets for diamonds, base metals, manganese, bauxite, kyanite, phosphate, etc.
▪ Little modern exploration carried out for most mineral commodities with the exception of gold and iron ore.
▪ National datasets for geology, airborne geophysics and mineral occurrences available in digital form.
▪ Modern mineral licensing system.
There have been major foreign investments in large iron ore projects in Liberia in the past five years. Iron ore production increased sharply between 2011 and 2013 due to the resumption of mining at Nimba and to improvements in the domestic infrastructure for ore handling. This production level was sustained in 2014 but the revenue from exports declined sharply due to the falling iron ore price. Increasing mechanisation in the diamond sector led to a substantial increase in production in 2014, while gold output remained at a low level of about 17 000 ounces. However, construction of a new gold mine at New Liberty, with annual production of 120 000 ounces, is on schedule and will provide a major boost to the national total from 2015.

Regional geology and metallogeny of West Africa

West Africa is underlain by the West African Craton which is exposed in the Reguibat Shield in the north and the Man Shield in the south. The outcrop of the Man Shield extends more than 1500 kilometres, from Senegal, Guinea, Sierra Leone and Mali in the west to Ghana and Niger in the east. In its western part the Man Shield comprises Archean rocks metamorphosed in the Liberian Orogeny (2.5–3.0 Ga), while the east is strongly affected by tectonothermal reworking in the Paleooproterozoic Eburnean orogeny (1.9–2.3 Ga), also known as the Birimian. Along its western margin the craton is bordered by a series of Neoproterozoic (Pan African, c. 550 Ma) belts, from the Mauritanides in the north, to the Bassarides in Senegal and the Rokelides in Sierra Leone and Liberia in the south.

Archean terranes are a source of major gold and diamond production worldwide but are also well known for a wide variety of economic deposits of other metals, most notably volcanogenic massive sulfide (VMS) copper-zinc deposits, iron ores, komatiite-hosted nickel-copper and paleoplacer gold-uranium. However, in the last 25 years it has been recognised that significant gold resources are also present in Proterozoic rocks in North and South America, Africa and Australia. In West Africa numerous world-class gold deposits have been identified in early Proterozoic greenstone belts related to regional scale faults and folds, just post-dating the emplacement of late tectonic granites. In addition, deposits of several other...
metals, including manganese, iron and aluminium, have been identified in Proterozoic rocks. Diamond production in the region is mainly from alluvial deposits in Sierra Leone with significant output also from Ghana, Guinea and Liberia.

**Archean**

The southern Archean part of the West African Craton is a granite-greenstone terrane, comprising older granitic gneisses and migmatites, with infolded supracrustal schist belts and younger granite intrusions. The gneisses and migmatites are thought to have been metamorphosed at c. 3.0 Ga during the Leonian Orogeny. The subsequent Liberian orogeny (2.5–3.0 Ga) resulted in deformation and greenschist facies metamorphism of the older gneisses and the schist belts. In Sierra Leone the schist belts are typical of Archean greenstone belts, comprising basal ultramafic schists overlain by mafic amphibolites, which are succeeded by metasedimentary rocks and minor acid volcanic rocks. In contrast the schist belts further east, in Liberia, are thinner, and are dominated by metasedimentary rocks including banded iron formations (BIF) which are important sources of iron and are associated with widespread placer gold mineralisation (Foster and Piper, 1993).

Gold production from the West African Archean has been relatively small with most derived from alluvial deposits in the schist belts of central and eastern Sierra Leone. Gold occurs in structurally-controlled quartz sulphide veins and sulphide-rich shear zones in the Sula-Kangari schist belt in the centre of the country. In Côte d’Ivoire, the Ity deposit is hosted by Archean-age amphibolites and calcareous metasedimentary rocks located within a few kilometres of the border with Liberia (Foster and Piper, 1993).

**Proterozoic**

Numerous world-class gold deposits are found in Paleoproterozoic rocks in Ghana, Guinea, Mali, Senegal, Niger, Burkina Faso and Côte d’Ivoire (Figure 2). The most important deposit types in West Africa are the world-class paleoplacers of the Tarkwaian, developed in south-west Ghana, and late-orogenic lode deposits hosted in Birimian greenstone belts, overlying the Archean basement. The estimated gold content of the major deposits in Ghana is huge and includes 14.2 million ounces at Tarkwa and 20 million ounces at Obuasi.

In addition to gold, deposits of other metallic commodities have been recognised, with greater variety in the early Proterozoic rocks of West Africa than in the Archean. Their formation is related to an accretionary event involving sedimentation and volcanism, accompanied by the emplacement of granitic plutons, during the Eburnean orogeny (Milesi et al., 1992). Economic deposits of iron ore, manganese, zinc, copper, nickel and bauxite are known, while smaller deposits containing titanium-vanadium, copper-molybdenum, copper-silver, antimony, tungsten, tin, niobium-tantalum and lithium have also been reported (Milesi et al., 1992). The most important pre-orogenic deposits comprise stratiform mineralisation of various types, including gold-tourmalinite deposits (e.g. Loulo in Mali), stratiform iron (e.g. Falémé, Senegal), zinc-gold-silver at Perkoa in Burkina Faso and manganese (e.g. Tambao in Burkina Faso, Lauzoua, Bondoukou and Ziémougoula in Côte d’Ivoire). The manganese deposit at Nsuta in Ghana, a major producer for 100 years, is considered to be syngenetic in origin with significant upgrading due to supergene enrichment processes (Mücke et al., 1999).

Major resources of bauxite are found in West Africa, notably in Guinea, Sierra Leone, Ghana and Mali. In 2012 Guinea was the fifth largest bauxite producer in the world with production of more than 17 million tonnes.

Known base metal deposits in West Africa are of relatively minor economic importance. A notable exception is the massive sulfide deposit at Perkoa in Burkina Faso which entered production in 2013. Reported reserves at the end of 2013 were 4.9 million tonnes at 9.9% Zn, 0.2% Pb and 41 g/t Ag (GlencoreXstrata, 2013). The origin of these ores, which are hosted by tuffaceous rocks and a later intrusive diorite, is unclear (Schwarz and Melcher, 2003). Small porphyry copper deposits are known at Diénéméra-Gongondy and Goren in Birimian greenstone belts of central Burkina Faso (Schwarz and Melcher, 2003) and significant disseminated copper occurrences are also known in possible Birimian rocks at Monogaga and Zéitouo in south-west Côte d’Ivoire.

**Geology of Liberia**

A major programme funded by the U.S. Agency for International Development (AID) and the Liberian Government, was carried out by the United States Geological Survey (USGS) and
the Liberian Geological Survey (LGS) between 1965 and 1972. Aeromagnetic and total count gamma radiation surveys were carried out in 1967–68 over the entire country. A total of 140 000 kilometres was flown, mostly along north–south lines, 0.8 kilometres apart on land and 4 kilometres apart over the continental shelf. The flight altitude was 150 metres above terrain. Geological maps for each of the ten quadrangles covering Liberia were compiled at a scale of 1:250 000 from interpretation of the airborne geophysical data and aerial photos, supplemented by field traverses along the major river courses. The main outputs from this were systematic files of basic geological information, including samples, thin sections and chemical analyses, together with airborne magnetic and radiometric maps and accompanying short descriptive reports. Subsequently, in 2007, the geological, geophysical and mineral occurrence data were compiled into digital form and released as a series of four national maps at a scale of 1:350 000. This digital compilation provides a comprehensive and readily accessible overview of Liberia's solid geology and known mineral occurrences and is an excellent basis for the identification of targets prospective for a wide range of metallic and non-metallic mineral commodities. Further processing of the legacy aeromagnetic data using modern software also has great potential for providing considerable additional geological detail and thus to highlight new exploration targets (Figure 3).

Liberia is underlain by the Man Shield, which comprises two major areas of Archean and Paleoproterozoic rocks. 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 (Liberian Geological Survey, 1982).

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, surrounds 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 widely considered to be equivalent.

Pan African (c. 550 Ma) age rocks underlie an elongate, fault-bounded zone along much of Liberia’s coastline. They comprise metasedimentary and mafic meta-igneous 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.

**Mineral resources of Liberia**

The United Nations Development Program (UNDP) conducted various mineral investigations in Liberia between 1968 and 1972. The programme, entitled ‘Mineral Survey in the Central and
Western regions, Liberia, produced a series of technical reports on a range of commodities including gold and base metals. In most cases there has been little or no follow-up of these investigations.

Important deposits of iron ore, gold and diamonds are known in Liberia and there is considerable potential for additional discoveries. These commodities are discussed in detail in separate brochures in this series. The location of the principal known deposits of other mineral commodities is shown in Figure 4.

**Metallic minerals**

**Uranium**

There has been little modern exploration for uranium in Liberia. Following completion of the national airborne geophysical survey, CLU Enterprises Inc undertook an exploration programme for uranium mostly in the central region of the country beginning in 1977. Ground checking of radiometric anomalies identified sporadic high values (up to 7000 ppm U) in rock and drillcore samples associated with pegmatitic bodies in granites and gneisses. There is considered to be potential for the discovery of small uranium deposits in Liberia, but additional exploration is required to locate them.

**Barite**

More than 40 barite veins are known in the vicinity of the Mount Gibi Ridge located about 95 kilometres north-east of Monrovia. Most of these were identified in the 1960s and 1970s and were evaluated by programmes of mapping, trenching and drilling by LGS, USGS and Dresser Minerals. The Mount Gibi Ridge comprises a large microgabbro dyke that trends about 300°, discordant to the regional strike which is north to north-north-east. The larger barite veins are parallel to the Gibi dyke and a common origin, or at least some common control, has been suggested for the emplacement of the dyke and the veins (Pomerene and Stewart, 1967). The largest veins are up to 5 metres wide and have a strike extent up to 170 metres. There are no modern estimates for the barite resources in the Mount Gibi area but it is...
considered that the district may contain 1–2 million tons of barite. The barite is reported to be of high purity (99% BaSO₄), suitable for chemical use and drilling mud. Dorbor (2010) reports a preliminary reserve estimate by Dresser Minerals in 1970 of 553 150 tons of barite in 19 veins to a depth of 500 feet (152 metres).

There has been a limited amount of recent exploration and extraction of barite from veins in the Mount Gibi district. Steinbock Minerals has produced barite and, up to April 2014, the company had exported 100 000 tonnes through the port at Buchanan.

Another significant barite occurrence is found at Wouta, Grand Bassa County (Mason, 1980). Two veins were identified with a strike length of 350 feet (107 metres) and widths of 4–8 feet (1.2–2.4 metres), but only limited subsurface investigations were carried out.

Further work is required to evaluate the potential for economic resources of barite in the Mount Gibi area and at Wouta. If hydrocarbon exploration, both offshore Liberia and neighbouring countries, increases significantly then these easily-mined, high-grade vein deposits, located close to the coast, are a potential source of barite for use in drilling muds.

**Bauxite**

There has been a long interest in bauxite in Liberia going back to the 1950s. Significant resources have been identified in two districts: at the Kolahun deposit in Lofa County in the north-west of the country close to the border with Sierra Leone; and at the Karloke deposit in the extreme south-east in Maryland County close to the border with Côte D’Ivoire (Massah, 1985). Preliminary surface investigations, with limited shallow trenching at Karloke, suggest the presence of grades of potential economic significance over wide areas although detailed systematic assessment, including core drilling, is required to assess the resource potential in both areas. The USGS recorded several additional occurrences of bauxite in the area around Karloke, but no details are available.

**Manganese**

In Liberia the most important manganese deposit is located at Mount Dorthrow, 70 kilometres south-east of Zwedru in Grand Gedeh County. The Cavalla River, which is the international boundary with Côte d’Ivoire, forms the eastern boundary of the deposit. Two types of mineralisation are present: sedimentary-metamorphic comprising banded manganiferous iron formations (Eburnean); and supergene iron-manganese enrichment. The manganiferous iron formations (itabirite), which are finely layered on a millimetre scale, locally grade into quartzite and elsewhere into higher grade, enriched ore types. The secondary mineralisation is derived from chemical and physical weathering processes under lateritic conditions in Tertiary to recent times. It comprises eluvial deposits on the hill tops and slopes together with an iron–manganese capping, referred to as canga, which is confined to a limited area on the crest of Mount Dorthrow. The LGS investigated the deposit by mapping and a limited programme of pitting and shallow drilling in 1980–81 (Sangmor et al., 1982). The deposit is characterised by a generally high Fe/Mn ratio, but sporadic high values, up to a maximum of 53% MnO, were reported in the surficial float and canga capping. The deposit was not considered...
to be economic at that time, but considerable additional work is required to evaluate the resources present.

Other indications of similar manganese enrichment associated with BIF in the supracrustal sequences of the Eburnean terrane were recorded by the USGS but no systematic assessments have been carried out (e.g. see Mason and Shannon, 1980). There has been no assessment of the potential in Liberia for the occurrence of carbonate ores of manganese, comparable with the Nsuta deposit in Ghana.

Heavy mineral sands

Heavy mineral sand deposits on beaches, in estuaries and offshore are an important global source of a range of metals including titanium, zirconium, thorium, rare earth elements and, locally, tin, tungsten and precious/semi-precious stones.

In Liberia preliminary surveys for heavy minerals were carried out by the UNDP in 1972 and 1973 along 300 kilometres of the Liberian coastline. Heavy mineral concentrations, comprising chiefly ilmenite with subordinate amounts of rutile and zircon and minor monazite, were found at several localities. Hancox and Brandt (2000) reviewed the heavy mineral potential of Liberia and summarised the historic investigations carried out, most of which were undertaken in coastal beach sands. They concluded that there are heavy mineral ‘reserves’ amounting to 744,700 tons along the entire coastline, with the most promising area being the 188 kilometre zone between Buchanan and the Sierra Leone border. However, the known deposits are small and, due to the low quality of the ilmenite, the economic value lies mainly in the contained rutile and zircon which comprise about 6% and 11% of the total heavy mineral content, respectively. It should be noted that the exploration undertaken to date has not been exhaustive and modern techniques have not been used with most work carried out by pitting with limited banka drilling.

No work has been done to search for relict beach systems that potentially could host larger and higher quality heavy mineral deposits.

Base metals (copper, lead, zinc, nickel, tungsten, tin)

By analogy with Archean greenstone belts elsewhere, there is potential for polymetallic base metal and gold mineralisation in these terranes in Liberia. However, little exploration for base metals has been carried out and few occurrences are known in Liberia.

There are some promising indications of tungsten-bearing mineralisation in Liberia. The most well known is in the Sam Davis Creek near Gondoja in Grand Cape Mount County (Sangmor and Dorbor, 1982; Dorbor, 2010). In this area work by the LGS identified enrichments in pegmatitic quartz of 1–5% scheelite associated with 1–2% Pb, Zn, Cu and up to 31 g/t Au + Ag. Another significant base metal occurrence is found at Tarjuh Hill 10 kilometres south-west of Juazohn, where low tenor enrichments in copper, zinc and nickel have been identified. Nickel values up to 1% were reported in lateritic soils at Tarjuh Hill (Richardson, 1980).

Dorbor (2010) also notes some evidence of base metal potential in Cape Mount County, Gbarpolu County and Bong County, but no work has been carried out to evaluate the potential in these areas.

Minor occurrences of low grade tin mineralisation have been reported from a few localities (Richardson, 1980). Most of these appear to be related to pegmatites found within the schist complex of the St John River Shear Zone, located about 95 kilometres inland from Buchanan along the LAMCO railroad, and its extension around Zia. UNDP (1972a) reported on investigations for tin over an area of 22 km² near Grebo where elevated cassiterite and columbite were identified in heavy mineral concentrates with values in rock up to 0.1% Sn. No systematic work has been done to evaluate the tin mineralisation in this belt and further investigations are required to determine the resource potential at Grebo. In addition more detailed mapping and sampling of the schist belts is needed to identify targets, especially for rare/minor metals associated with pegmatites.

Nickel, copper, platinum-group metals (PGM) and chromite in mafic-ultramafic rocks

Potential exists for nickel – copper – PGM in a variety of settings in association with mafic-ultramafic rocks in the basement. By analogy with known deposits worldwide, prospective targets include PGM in layered complexes, nickel-copper sulphide deposits ± PGM in marginal, contaminated or deformed zones in
mafic-ultramafic intrusive bodies, nickel ± PGM in komatiitic rocks, and hydrothermal PGM in structurally-controlled settings in serpentinites. There is also potential for supergene nickel ± cobalt in laterites developed over ultramafic rocks and for the development of PGM-bearing placer deposits derived from ultramafic source rocks.

Although there have been no studies of these targets, the presence of a wide range of mafic and ultramafic rocks, commonly deformed and altered, suggests that further investigation is merited. Of particular note are the Juazohn intrusive complex (serpentinite, dunite, pyroxenite) in Sinoe County (Tysdal, 1975), the Gohn Zulu ultrabasic body in Cape Mount County and the norite body at Cape Mount, near Robertsport (Dorbor, 2010). In addition the published geological maps indicate the widespread occurrence of ultramafic rocks in western Liberia, particularly in the Bopulu quadrangle map. It is considered likely that additional ultramafic bodies are present in this region that were not recognised during the reconnaissance mapping carried out by USGS and LGS.

Potential also exists for chromite mineralisation in association with layered mafic-ultramafic intrusive complexes and as podiform deposits in serpentinites. USGS recorded about 500 chromite occurrences, either in alluvium or by chemical analysis, but no association with bedrock mineralisation has been demonstrated. Richardson (1980) noted that massive chromite was formerly mined in the North Kambui schist belt in eastern Sierra Leone. Given that these rocks extend into western Liberia in the Kumgbor forest region it was suggested that this area should be investigated for similar chromite mineralisation.

The prospectivity of Archean terranes for magmatic nickel-copper-PGM and chromite mineralisation in West Africa is further highlighted by the occurrence of deposits of these types in the Samapleu area of western Côte d'Ivoire close to the border with Guinea (Sama Resources, 2013). Significant enrichment of nickel and cobalt in laterites has been demonstrated in the same area.

Significant PGM mineralisation (primary and alluvial) is known in the early Jurassic Freetown Igneous Complex located along the Atlantic coast in Sierra Leone (Bowles et al., 2000). Basic dykes of this age are known to occur in the coastal strip of Liberia and these should be examined for magmatic nickel-copper-PGM mineralisation.

**Technology metals (niobium, tantalum, rare earth elements, lithium, beryllium)**

A range of minor metals used chiefly for new and green technologies is of great interest to governments in the West because of the possibility of supply disruption. Many of these are by-products of the extraction of major metals such as copper, nickel or zinc, while others are derived from deposits in which they are the main commodity produced.

Granitic pegmatites are potential sources of many minor metals including lithium, rubidium, caesium, beryllium, gallium, scandium, yttrium, rare earth elements, tin, niobium, tantalum, uranium, thorium, zirconium and hafnium. The coarse grain size and high purity of their non-metallic (industrial) mineral components also makes them attractive exploration targets that might support small-scale extraction of both ore and industrial minerals. They also have potential as sources of semi-precious stones, such as rose quartz, aquamarine and tourmaline.

Most tantalum deposits are hosted by peraluminous pegmatites and granites with columbotantalite group minerals (commonly referred to as 'coltan') the most important hosts for tantalum. Major sources of tantalum from pegmatites are found in Canada, Western Australia and Brazil. In Africa there has been production from pegmatites over long periods, notably in the Democratic Republic of Congo, Ethiopia, Namibia and Mozambique. In many cases the extraction is from shallow, small-scale workings and related eluvial and alluvial deposits derived from pegmatite sources. Significant niobium-tantalum deposits, sometimes associated with tin and tungsten ores, are also found in peraluminous granites in China, USA, Egypt, France, Russia and the Czech Republic.

Dorbor (2010) reported the presence of columbite-tantalite in concentrates from soils and stream sediments, mostly in western Liberia. USGS also reported columbite-tantalite at more than 440 localities, either in alluvium or by chemical analysis. These are widely distributed and are found both in the eastern part of the Archean terrane and in the Proterozoic terrane with many
occurrences close to the border with Côte d’Ivoire. These coltan occurrences may owe their origin to concentration through superficial processes during prolonged tropical weathering. Exploration for coltan-bearing pegmatites in Liberia would present a formidable challenge. Although pegmatites are widespread, especially in proximity to granite bodies, they are commonly thin and discontinuous in form and few are recorded on the 1:250 000 scale geological maps of Liberia.

Alkaline rocks are not well known in Liberia, although syenite is present at Tarjuh Hill and trachyte dykes have also been more widely recorded in the Juazohn region. Given that alkaline and peralkaline granites and syenites are potential sources of niobium, tantalum, zirconium and rare earth mineralisation, these rocks merit further investigation in Liberia.

**Industrial minerals**

**Kyanite**

Kyanite-bearing gneisses and schists are developed in an elongate belt about 14 kilometres long and 1.6 kilometres wide within the Archean terrane located about 20 kilometres north of Buchanan, Grand Bassa County. The kyanite resources at Mount Montra, the most prominent hill in this belt, were studied initially by the LGS (Stanin and Cooper, 1968), with later more detailed investigations including drilling and resistivity surveys (UNDP, 1972b). Preliminary estimates suggested the presence of up to 10 million tonnes of kyanite-bearing rock containing approximately 2.5 million tonnes of kyanite. Considerably more work is required to quantify this resource and to determine the grain size and homogeneity of the contained kyanite. The proximity of the deposit to a paved road and to a sea port may confer significant economic advantages and make this a viable mining proposition.

**Phosphate**

A phosphate deposit of potential economic significance is located near the town of Bambuta, about 70 kilometres north-north-east of Monrovia and 25 kilometres east of the Bomi Hills former iron ore mine. High-grade phosphate rock, identified in this area by the LGS in 1969, was soon after investigated by the Liberia Mining Company Ltd who undertook a programme of core drilling (25 boreholes total, average depth 28.9 metres) and mapping. The mineralisation comprises a layer of phosphate rock up to 38 metres thick underlying banded iron formation and resting on older granitic gneiss. The drilling data indicated a tentative 'minimum reserve' of 1.5 million tonnes of phosphate rock grading 28% P₂O₅ or 1 million tonnes at 32% P₂O₅. Furthermore, Van Rooijen (1971) noted that the 'ore' is highly heterogeneous in texture and that the phosphate grade varies greatly both laterally and vertically. Mineralogical study of drillcore shows the phosphatic layer to range from iron to aluminium phosphates with the predominant mineral being aluminium strengite, an orthorhombic iron phosphate containing some aluminium (FePO₄·2H₂O) (Rosenblum and Srivastava, 1979). Further investigations are required to determine the suitability of this deposit as an economic source of phosphate for use as fertiliser or for other purposes.

**Clay**

Dorbor (2010) noted that kaolin-rich clay deposits are known at three localities: (1) Bushrod
Island – New Georgia, located near Monrovia; (2) the Harbel Firestone plantations; and (3) Tapital-Diala. Only the first has been investigated (Blade, 1969) where they are suitable for ceramic, high quality bricks and pottery. A reserve of 8 million tonnes was estimated for the readily accessible part of the deposit. The small Harbel deposit was previously used by the Firestone Plantations Company for making bricks. Shannon (1979) reported that the clay in the Tapita-Diala deposit is very pure kaolin, although no other information is available.

These sources of clay remain of potential economic value to local industry, although they have not been properly mapped and no systematic geological assessment has been carried out.

**Silica sand**

Silica sand is an important commodity used mainly in glassmaking. It is valued for a combination of chemical and physical properties including high silica content and low levels of deleterious impurities, such as clay, iron oxides and heavy minerals. Silica sands typically have a narrow grain size distribution in the range 0.5 to 1 millimetre.

Silica sand deposits have long been known along the coast, mainly between Monrovia and Marshall, a distance of about 45 kilometres, extending inland up to 20 kilometres (Rosenblum and Srivastava, 1970; Sangmor, 1976). Other deposits found along rivers in the interior have not been evaluated.

Pitting and drilling, with supporting mineralogical studies, conducted in the late 1960s and 1970s on the coastal deposits suggested a 'reserve', based on an average thickness of 1 metre, of about 136 million tonnes of good quality sand suitable for glass manufacture. A small programme of additional drilling focussed on an area near Schiefflin identified at least 2.7 million tonnes of high grade silica sand (Shannon and Richardson, 1979), while Dorbor (2010) suggested that a total of about 4 million tonnes of high quality silica sand may be available. Before the civil unrest, the deposits in the Schiefflin area were used by the Pan African Glass Factory to manufacture glass bottles, but it has been reported that some of the resources in this area have effectively been sterilised by recent urban development. There is currently some commercial interest in developing the silica sand in certain areas, but no details are available.

**Mineral potential of Liberia**

By analogy with Precambrian terranes elsewhere, Liberia is considered to be highly prospective for a wide range of metallic and industrial mineral deposits. Elsewhere in West Africa world-class resources of gold and iron ore are widely known and high levels of exploration for non-ferrous metals, especially gold, have been sustained for long periods. The region also has a long history of mining bauxite and manganese, while the base metal potential has only been appreciated more recently with the discovery of significant deposits of zinc and nickel-copper.

By comparison with other countries in West Africa the geology of Liberia is poorly known and there has been very little systematic modern exploration carried out for most commodities, with the exception of gold. The available digital data on geology, airborne geophysics and mineral occurrences for the whole country provide an excellent basis for the identification of additional exploration targets but more detailed investigations are required to characterise these more closely. For example, the location, nature and extent of mafic-ultramafic rocks in Liberia need to be better determined in order to identify potential targets for magmatic nickel-copper-PGM and chromite deposits. Re-processing of the legacy aeromagnetic data provides a highly cost-effective way of providing additional information on the bedrock geology and structure of Liberia.

The majority of the known mineral occurrences described in this brochure were investigated during the late 1960s and 1970s in a cursory manner using mainly low-cost techniques. Further detailed field surveys using modern techniques are required to evaluate their economic potential. These should include geological mapping and geochemical sampling of stream sediments and overburden, supplemented, where appropriate, by ground geophysical surveys to elucidate geology, structure and other controls on mineralisation. Mineralogical and chemical analysis of heavy mineral concentrates from stream sediments is an effective complementary technique that can be useful in exploration for precious metals, gems, tin, tungsten, barite and base metals. Sub-surface
investigations at these locations have generally been very limited and considerably more drilling is required to elucidate the extent and quality of mineralisation present.

In addition to the major industrial metals, such as iron, aluminium, copper, nickel and zinc, it is also important to consider the potential for a range of minor metals and industrial minerals, often now referred to as critical raw materials, which are of increasing importance for new and green technologies. For example, available information on metals such as antimony, chromium, cobalt, gallium, germanium, indium, lithium, niobium, the platinum-group metals and the rare earth elements is largely unavailable in Liberia and yet modern analytical methods mean that high quality data for most of these are available routinely and at low cost. Similarly, a range of industrial minerals, such as fluor spar, graphite and phosphate rock, are also much sought after by many advanced, manufacturing economies in the West.

Mineral policy and mining law in Liberia

The mining law in Liberia is set out in the New Minerals and Mining Law (NMML) of 2000, which was later strengthened by the Public Procurement and Concessionary Commission Act (PPCCA) of 2006. Under the NMML ownership of minerals is vested in the Republic of Liberia. The Ministry of Lands, Mines, and Energy (MLME) has the statutory role to coordinate the development of all land, mineral, water and energy resources of Liberia. MLME published the national mineral policy for Liberia in 2010 which aims to deliver ‘equitable and optimal exploitation of Liberia’s mineral resources to underpin broad-based sustainable growth and socio-economic development.’ It provides a coordinated policy framework to facilitate the development of an internationally competitive mining sector and to promote regional and international trade. It also aims to improve the knowledge of Liberia’s mineral endowment and to provide a stable and effective legal and regulatory framework to ensure transparency, security of tenure and to regulate and monitor exploration and mining activity. The NMML and associated mining regulations are currently being updated.

Under the current mining law there are a number of classes of mineral titles, summarised in Table 1. Exploration rights are divided into three types: reconnaissance, exploration and prospecting licenses. A reconnaissance license is issued for a period of six months for the purpose of a rapid geological assessment of the terrain as determined by background research and desk studies. No drilling, trenching or pitting is permitted under the terms of a reconnaissance license. An exploration license provides exclusive rights for three years that may be extended for a single two-year period upon surrender of 50 per cent of the initial area. A prospecting license covers an area up to 100 acres and is valid for six months, and is renewable once for a further six months.

There are three types of Mining Licenses, denoted Class A, B and C. Class A Mining Licenses are issued for an initial period of 25 years on the basis of an approved feasibility study, conducted to international standards, and an approved Environmental Impact Study. A Class B Mining License is issued for an initial period of five years subject to an approved production plan for ‘industrial...
mining’. The terms of the license allow up to 15 license holders to collectively mine through a cooperative scheme. A Class C Mining License is granted for an initial period of one year over an area not exceeding 25 acres. The license is restricted to a ‘Small-Scale Operation’ but license holders can engage in cooperative mining activities. Under the terms of the NMML an applicant for an exploration license or Class A Mining License must also conclude a Mineral Development Agreement with the government defining the precise terms of the license. Administration of mineral licenses is facilitated by a modern digital Mining Cadastre Administration System (MCAS) which is located at the Cadastre Office of the MLME.

The government of Liberia is strongly committed to encouraging high standards of transparency and accountability and has been compliant with the EITI (Extractive Industries Transparency Initiative) since 2009.

**Further information**

The LGS holds the digital files for the national geological, airborne geophysical and mineral occurrence datasets generated by the surveys carried out by the USGS and LGS between 1965 and 1972. Reports from the UNDP minerals programme of the same era and others describing later mineral investigations are also held in digital form by the LGS.

Further information on mineral licenses and how to apply for them is available from the Cadastre Office of the Ministry of Lands, Mines and Energy in Monrovia.

**References**

Unless otherwise stated these are available from the LGS.


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**Table 1 Key features of the mineral license types available in Liberia.**

<table>
<thead>
<tr>
<th>Mineral Title/License Type</th>
<th>Maximum Area</th>
<th>Duration</th>
<th>Conditions and Restrictions</th>
<th>Other Key Aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reconnaissance</td>
<td>2000 km²</td>
<td>6 months</td>
<td>No drilling, trenching or pitting.</td>
<td>One six month extension allowed.</td>
</tr>
<tr>
<td>Exploration</td>
<td>1000 km²</td>
<td>3 years</td>
<td>Land area contiguous. Exclusive rights. Programme of work approved by MLME.</td>
<td>One 2-year extension permitted, subject to surrender of 50% of original area.</td>
</tr>
<tr>
<td>Prospecting</td>
<td>100 acres (0.4 km²)</td>
<td>6 months</td>
<td>Commercial mining not allowed.</td>
<td>One six month extension allowed.</td>
</tr>
<tr>
<td>Class A Mining</td>
<td>25 years, renewable</td>
<td></td>
<td>Approved feasibility study and environmental impact study required.</td>
<td>Demonstrated technical competence and financial resources to undertake the work.</td>
</tr>
<tr>
<td>Class B Mining</td>
<td>5 years, renewable</td>
<td></td>
<td>Industrial mining allowed. Up to 15 license holders may work in cooperation.</td>
<td></td>
</tr>
<tr>
<td>Class C Mining</td>
<td>25 acres (0.1 km²)</td>
<td>1 year, renewable</td>
<td>Citizens of Liberia only.</td>
<td>Cooperative mining activities allowed.</td>
</tr>
</tbody>
</table>


Authorship and acknowledgements

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BGS Project Leader: Joseph Mankelow

For further information please contact:
The Director, Liberian Geological Survey
c/o The Ministry of Lands, Mines and Energy,
P.O. Box 10-9024, Capitol Hill, Monrovia, Liberia

http://www.molme.gov.lr/

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