

Iron

June, 2016

This report provides an overview of Iron from historic, published and unpublished sources. It is intended to only hi-lights contextual information with particular reference of Iron Ore mineralization, occurrences and related mining activities across Sierra Leone. Iron occurs in the schist belts of the greenstone terrane and therefore prospecting is highly recommended.

Iron:

Iron ores are rocks and minerals from which metallic Iron can be economically extracted. The ores are usually rich in iron oxides and vary in color from dark grey, bright yellow, deep purple to rusty red.

Definition:

Iron is a lustrous, ductile, malleable, silver-gray metal. It is known to exist in four distinct crystalline forms. Iron rusts in damp air, but not in dry air. It dissolves readily in dilute acids. Iron is chemically active and forms two major series of chemical compounds, the bivalent iron (II), or ferrous, compounds and the trivalent iron (III), or ferric, compounds.

Name	Formula	% Fe
Hematite	Fe ₂ O ₃	69.9
Magnetite	Fe ₃ O ₄	74.2
Gothite / Limonite	HFeO ₂	~ 63
Siderite	FeCO ₃	48.2
Chamosite	(Mg,Fe,Al) ₆ (Si,Al) ₄₁₄ (OH) ₈	29.61
Pyrite	FeS	46.6
Ilmenite	FeTiO ₃	36.81

Table 1 Major Iron Compounds

Iron ore was discovered in Sierra Leone in 1926 in the Marampa area near Lunsar and was mined from hematite schist in an open pit.

Further prospecting in the past and at present have led to the discovery of other iron ore deposits with predominantly magnetite as main iron mineral known from the Sula Mountains, the Gola Rain Forest area and east of Lake Mabesi area.



Figure 1 A typical Hematite Specimen from Tonkolili Iron Deposit

Table 2 Selected Properties of Iron

Symbol	Fe	
Atomic Number	26	
Appearance	Vary in color from dark grey, bright yellow, deep purple to rusty red	
Ionic radius	0.076 nm (+2); 0.064 nm (+3)	
Mass	55.85 g.mol ⁻¹	
Melting Point	1538°C	
Boiling Point	2861°C	
Electronegativity according to Pauling	1.8	
Specific Gravity	7.874	at 20°C
Density	7.8 g.cm ⁻³	at 20°C
Isotope	8	
Standard potential	- 0.44 V (Fe ²⁺ / Fe); 0.77 V (Fe ³⁺ / Fe ²⁺)	

Deposits in Sierra Leone.



Figure 2 Operational Iron Ore Mine at Farangbaya, Tonkolili, Northern Sierra Leone

Tonkolili Iron Ore Deposit

Tonkolili iron ore deposit is located within the Sula Mountain range and forms part of a banded iron formation (BIF) featuring a north east-south west trending magnetic anomaly. The mine contains four contiguous ore bodies, Simbili, Marampon, Numbara and Kasafoni. These are underlain by amphibolites, amphibolite-hornblende schists, phyllites and amphibolites associated with basaltic lava flows of the Sonfon Formation.

Each of the ore bodies is open at depth and characterizes primary magnetite mineralization underlying the secondary hematite/goethite style mineralization.

The mine contains 12.8 billion tonnes of Joint Ore Reserves Committee (JORC) compliant iron ore resources (11.5 billion tonnes of magnetite ore). It is considered to be one of the world's largest magnetite deposits.

Lunsar Iron Ore Deposit

The Marampa Iron ore deposits form part of a greenstone belt with massive beds of specularite schist interstratified with quartz-mica schist. The formation has been traced as far as Kukuna near Guinea border and to the south at Toma and Makalawa.

A typical section through the upper part of the

deposit shows a capping of cemented hard red hematite and laminated hard red and bluish-grey ore passing downward into soft schistose specular hematite and hematite schist.

Large quantities of powder ore averaging form 50-55%. Iron have been proved and sections in adits show that the powder ore consists of beds of schistose hematite, hematite schist composed of specular hematite, quartz and some muscovite and narrow beds of soft mica schist essentially of white mica and quartz.

The primary ore bodies within the deposit consist of 122.8Mt inferred resources graded at 31.19% Fe. The tailings portion of the mine contains an estimated 42.5Mt of indicated resources graded at 21.67% Fe. The newly discovered Campbell town ridge and Hospital ridge structure are connected to Marampa's Masaboim Hill and Ghafal Hill zones.

A company started production at the Marampa mine in December 2011 and in 2013 produced 3.4 million wet metric tonnes of sinter concentrate. Marampa has a mineral resource of over 1 billion tonnes of iron ore including a probable reserve of 539Mt grading 31.1% Fe, sufficient for over 40 years of mine life.



Figure 2 Ore Haulage by Road from Marampa to Thofayem (Shallow Water Port)

Another deposit in the vicinity of Lunsar, **The Marampa Iron Ore Deposit** ("Marampa") operated by Cape Lambert PLC has an advanced hematite iron ore project at feasibility assessment and permitting stage located 90km northeast of the capital.

The project has four deposits with an Indicated Resource of 262 million tonnes at 28.7% iron and an Inferred Resource of 419Mt at 27.9% iron.

Marampa has a coarse primary grind size, low power costs, life of mine average mass yield of 36.4% and production of greater than 65% iron concentrate. The company has recently been granted a large scale mining license for its wholly-owned Marampa Iron Ore Project and is now in the process of negotiating its mine lease agreement.



Figure 4 Ship Loading Facility at Pepel

Kukuna Iron Deposit

The Kukuna deposit was first investigated in 1962 by Demag. The deposit consists of two parallel haematite schist horizons with a strike length of about 18km. The horizons vary from 43 to 60 meters in width and are approximately 280 – 900 meters apart.

Detailed regional mapping and sampling carried out by SRK consulting Pty Ltd in June 2010 confirming extensive occurrence of folded specularite hematite mineralization. Conducted ground based induced polarization (IP) geophysical survey across 14 km strike length in 3/2011. Survey identified 54 chargeable anomalies shown to be closely related to specularite-hematite schist mineralization. Survey was carried out by SAGAX Afrique. 14,501 m of scout drilling conducted in 68 holes 7 -11/2011 Cores oriented photographed, logged and sampled. All holes down-hole surveyed assay results confirmed specularite-hematite mineralization with significant grade to depth of up to 250 m. In 2012, SRK consulting (UK) Ltd conducted a structural evaluation of drill cores so as to provide a 3D geological model of

resource.

Sokoya Iron Deposit

The Sokoya deposit is situated within and marginal to the Sula Mountains Greenstone Belt in the Archaean granitic basement. It is generally agreed that two orogenic episodes affected the area and resulted in the development of a major Infracrustal basin that was subsequently metamorphosed during a second event (i.e. Liberian) to form the Kambui Group greenstones that uplifted as the Sula Mountains.

Northern Mining Company Limited has estimated its Sokoya resource to contain several thousand tonnes of industrial ore resources explored for during the exploration stage with an average Fe grade of 22.18% and 32.15%. Among these resources, there is another 135,754,900 tons of industrial ores with an average Fe grade of 33.42% and 22.37%.

Aside from mineral resources estimated above, there is also an oxidized iron ore found at the earth's surface of the mine area. According to the oxidized ore outcrop area and drilling data, it is estimated that there is in excess of 800,000 tons of oxidized ore with an encouraging Iron grade.

Malonpo Iron Deposit

The Malonpo deposit is situated within and marginal to the Sula Mountains Greenstone Belt in the Archaean granitic basement region of Sierra Leone. Mass Energy Mining Company Limited has estimated its resource to contain several million tonnes of industrial ore resources explored from three (3) anomalous areas.

Sula North Iron Deposit

The deposit is also located in the Sula Mountains greenstone belt of Sierra Leone approximately 200 km from the Pepel deep water port near Freetown.

This is the north ward extension along strike of the banded iron formation within the Tonkolili Iron Mine to the immediate north.

This part is licensed to Blue Horizon SL Limited and is contiguous with the ore body in the southwards

The in-ground tonnage is likely to be at least as much as that in the southwards extension. Initial exploration work is currently underway to define the resource potential and economic viability.

The Bagla Hill Deposit

The Bagla Iron ore deposit occurring in south eastern Sierra Leone is a metamorphosed banded magnetite silicate rock made up of alternating layers of magnetite and quartzite; forming part of the Mano-Moa Granulites. The three main sections of the Ironstones trend northeast, parallel to foliation, and have a total outcrop area of about 1.7 million square metres.

Preliminary evaluation work by Bethlehem Steel Mining Company gave an ore reserve estimate of 384 million tons of primary ore (magnetite) at 18.1% Fe and about 90 million tons of haematite ore at 34.3% iron. Initial beneficiation work revealed that the iron content could be upgraded to 52.3%.

The deposit is presently within a protected forest area. With no mineral rights awarded. Although the ironstones east of Moa River are probably all unpayable or at best marginal at present, they are of interest because very large tonnages of them crop out as hills rising several hundreds of meters above ground and well within 70 kilometres of the sea.

The deposit lies some 10 km north-east of the Mano iron ore mine in Liberia that was exploited between 1958 and 1983 by the National Iron Ore Co. Ltd Ore from the mine was transported approximately 130 km by rail to port facilities in Monrovia. The area is presently a declared forest reserve.

Lake Mabesi or Funyehun Iron Deposit

There is an Iron Ore deposit in the Lake Mabesi area. The ore consists of a quartz- magnetite - gneiss. The magnetite bearing gneisses and associated garnetiferous quartzites occur in four main horizons. Two of these in the west of the area and south of Gbenge are arcuate in form.

The northern band is 3.2 km long and the southern one is 4.8 km. Further east about 800 m to the east of the town of Jabama there is a NNW trending band. Widths are variable between 30m and 200m. Two ore samples have been assayed at 40.5 and 42.7% Fe.

The Iron deposits extend eastwards across two geological boundaries and onto the Liberia international boundary. It has weak magnetism, mainly consisting of 25-30% hematite 5-10% limonite and 5-10% residual magnetite. The gangue is mainly made up of 30-40% quartz and little chlorite.

The primary ore has relatively strong magnetism, the mineral composition is quite simple, mainly consisting of 25-40% magnetite. The gangue is mainly made up of Quartz and trace minerals including pyrite, apatite chalcopyrite and zircon.

Orebody contacts with wall rock comfortably whilst secondary minerals are mainly made up of carbonate, Kaolin, chlorite, limonite and sericite.

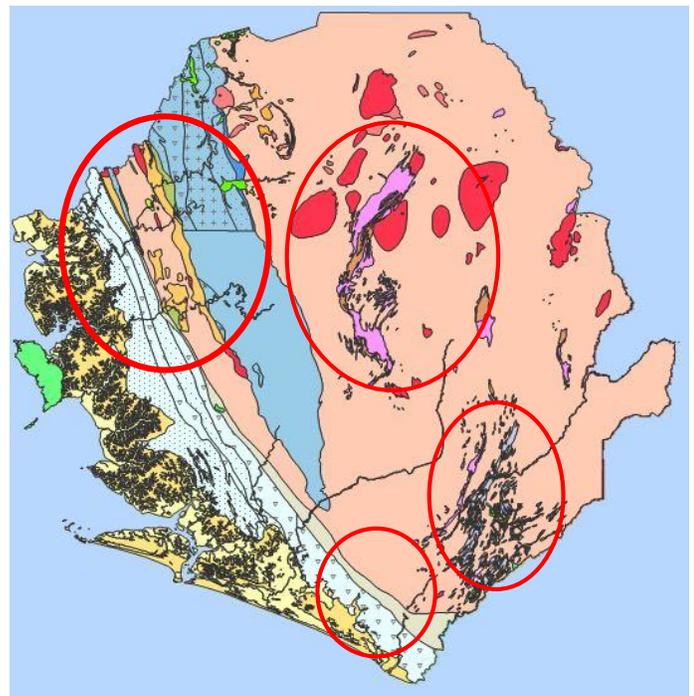


Figure 5 Locations of Sierra Leone Known Iron Ore Deposits – Data Sources GIMS- NMA 2016

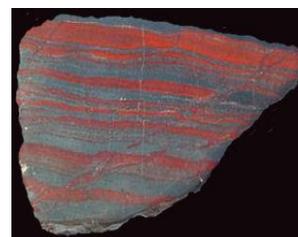


Figure 6 Hematite Specimen



Figure 7 Specularite Hematite Schist

Uses of Iron

One of the most ubiquitous products in Sierra Leone and the world over is corrugated iron, a structural sheet steel shaped into parallel furrows and ridges. Iron was first invented by Henry Robinson Palmer in 1828 and quickly became popular for roofing.

Steel is a processed form of pig iron with impurities such as silicon, phosphorus and sulfur removed and with a reduction in the carbon content. Globally, steel's versatility is unsurpassed. Wrought iron (low carbon) and cast iron (pig iron) also have important markets.

Iron is a strong metal that is not that expensive. It is fairly cheap that's why it is commonly used in manufacturing machine tools, automobiles, hulls of large ships, machine parts, and even in the construction industry. A good chunk of structures today are made of metallic iron.

Iron is also common in many different tools, surgical equipments, and appliances. Stainless steel is a common type of steel used in a host of different products. It is created when iron is combined with other metals.

It is 100% recyclable and is used in aircrafts and automobiles. The use of stainless steel and iron in this form makes everything in our world today working perfectly fine.

Iron metal may be produced from the smelting of certain iron compounds. Their concentration in economic proportions is referred to as 'iron ore'.

Other well-known uses of iron compounds are:

- Iron sulfate used as fungicide, the oxalate of iron in photographic development, limonite, goethite, hematite as pigments and abrasives, magnetite in the production of industrial electrodes and also for washing coal
- Iron chloride and nitrate used as mordants and industrial reagents in the production of several types of inks
- Iron carbonyl as a catalyzer of many chemical reactions
- Micaceous hematite as a protective paint on steel superstructures

The statement 'iron is everywhere' is true. It is not an understatement. It is a fact that you can find iron or a form of it, wherever you may be. Some may not be visible to the naked eye but still exists.

Further Reading and Selected References.

Useful contacts for further information.

The Mineral Potentials of Sierra Leone by Dr. Klaus Peter-Freitag (1974)

Mineral Potentials of Sierra Leone Vol 1 and 2.

Geology of Sierra Leone

<http://www.nma.gov.sl/home/library-services/>

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