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## **The Geology, Mineral Resources of Sierra Leone and how the Resources can be used to develop the nation**

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### **Abstract**

*Sierra Leone forms part of the West African Craton whose counterpart is the Guyana shield. Two main structural divisions are recognized; (a) the Liberian granite-greenstone terrain and (b) the pene-contemporaneous Kasila group mobile belt. Radiometric ages from both divisions show a spread from 2100 Ma to over 3400 Ma. The rocks in the country are predominantly Archaean consisting of a granitic basement containing elements of sedimentary, mafic formations and a group of supracrustal greenstone belts with banded ironstones and detrital sediments. In common with most Archaean terrains, the country has considerable mineral deposits and reviews of these deposits have been based on similarities between the Archaean of Sierra Leone and that of the Superior province in Canada or the Rhodesian craton in South Africa. In this study, the country's primary mineral resources which are diamonds, rutile, gold, bauxite, and iron ore are discussed. The production or mining of these resources contributed about 20% of GDP and up to 15% of fiscal revenues until the closure of some mines before the civil war and the others during the war. It is believed that if the economy of this post conflict nation is to grow stronger the mining industry will have to serve as an engine to its economic growth. Four recommendations have been proposed on how current and prospective Sierra Leonean governments will achieve their developmental objectives using revenue generated from the mining of these mineral resources.*

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### **1. INTRODUCTION**

The Republic of Sierra Leone is a small coastal West African country bordered by Guinea in the North and East, Liberia in the South and the Atlantic Ocean in the West. Almost half of the country consists of coastal lowlands with extensive mangrove swamps. To the east of the coastal plains are rolling wooded hills, leading into mountainous plateau areas. The climate is hot and humid with annual precipitation reaching more than 3,000 mm. The country has an area of 71,620 square kilometers (km<sup>2</sup>) and had an estimated population of approximately 6.5 million in 2007. The country was ravaged by a brutal civil war from 1991 to 2002 which had catastrophic impacts on human lives, properties, and the economy.

However, the country is endowed with a large resource base. This research emphasis on the mineral sector and the primary mineral resources are diamond, rutile (Titanium Oxide), bauxite, gold, Iron ore plus the recently discovered Oil and Gas deposit on the shores of the country in Sulima towards the boundary with Liberia. Figure 1 shows the

country's primary mineral distribution. Before the civil war, the country had established an active mining sector built upon significant exports of diamonds, rutile, gold, iron ore and bauxite. Although relatively modest by global standards, the mining sector was significant in terms of the country's population and GDP. It underpinned much of the country's formal economic activity, contributing 20% of GDP, as much as 15% of fiscal revenues and accounting for over 90% of exports.

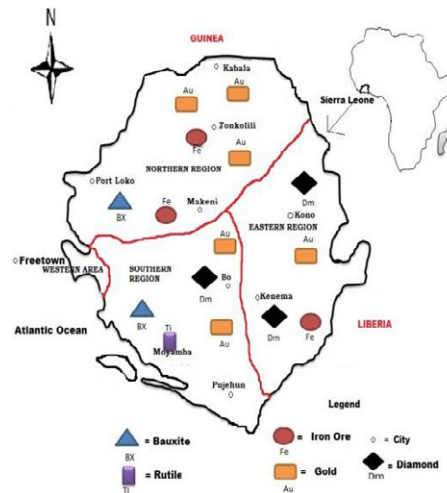


Fig 1 The map of Sierra Leone, its mineral distribution and its position in Africa.

Mining and quarrying provided a livelihood for over 250,000 people, and employed about 14% of the total direct and indirect labor force. Despite the sector operating at only a fraction of its potential, its contribution was significant enough to qualify Sierra Leone as a resource-rich country.

The return to political stability in 2002 coupled with positive global developments in the mining sector has now seen the rejuvenation of the domestic mining sector and it is hoped that this rejuvenated sector will once again underpin the economy and support the government's developmental objectives.

This research is aimed at reviewing the country's geology, its mineral resource endowment and how the mining of these resources could be useful in alleviating poverty and develop this post conflict country.

## 2. GEOLOGICAL STRATIGRAPHIES AND THEIR ASSOCIATED MINERAL DEPOSITS

About 75% of the country is underlain by rocks of Precambrian age, with a coastal strip of about 50 km in width comprising marine and estuarine sediments of Tertiary and Quaternary to recent age. Figure 3 shows the seven major structural units recognized in Sierra Leone. These structural units are discussed below as follows:

### a) The Granite-Greenstone Terrain.

It represents parts of an ancient continental nuclei located on the edge of the West African Craton. Regional reconnaissance mapping indicates supracrustal rocks and basic and ultrabasic intrusions. The infracrustal gneisses and granitoids were formed and reworked during two major orogenic events, an older Leonean event (2950-3200 Ma) and a younger Liberian event (2700 Ma). The Leonean event commenced with the intrusion of a basic igneous suite and by the formation of a greenstone belt represented by the Loko Group which is now deeply eroded. Other volcano-sedimentary sequences are preserved within the granites, gneisses and migmatites. Highly folded greenstone belts predominate in the north and central Sierra Leone. Figure 2 shows a folded Quartz-Mica Schist in northern Sierra Leone. These greenstone belts are the principal hosts of the gold mineralization in the country. Other associated mineral deposits include molybdenite, columbite-tantalite and chromite.

### b) The Kasila Group

The Kasila group is a high grade metamorphic belt with rocks trending in the NNW direction. It comprises a high-grade series of granulites, consisting of garnet, hypersthene and hornblende gneisses, quartzites and associated migmatites. In Sierra Leone, this group bounds the main part of the West African craton on its west and southwestern margin. Where the Kasila Group is eroded, significant secondary deposition of titanium minerals (Rutile and Zircon) have been formed. Weathering of this Group has also deposited bauxite.

### c) The Marampa Group

This group is subdivided into two layers; a lower, Matoto formation consisting of basic pillow lavas, serpentinites and andesites; and an upper, Roktolon formation consisting of psamites, pelites and banded iron formations (Macfarlane et al., 1974). The Marampa Group is bounded on its eastern margin by a tectonic contact and it is important for its Iron ore deposits.

### d) The Rockel River Group

Comprises of Precambrian to Cambrian sedimentary and volcanic assemblages deposited unconformably on a basement complex. Deposition was probably in a fault-bounded basin along the Rockel-Kasila boundary following the formation of the tectonic zone at the end of the Liberian or during the Eburnean orogeny. The Rockel River Group was deformed during the Rockelide orogenic episode (550 Ma). Deformation increased in intensity westwards.

### e) The Saionia Scarp Group

This group forms a small ingression into Sierra Leone in the northwest of the country, and is composed of horizontally bedded arkoses, grits and shales with intruded dolerite sills. This group belongs to that part of the *Gres Horizontaux* of Guinea which has been classified as Ordovician, based on the discovery of the graptolites *monograptus reccartonensis* in shales near Telimele. In Sierra Leone, the Saionia Scarp Group rests unconformably on the Rockel River group.



Fig.2. Macroscopic folding of Quartz-Mica Schist in the Granite Greenstone Terrain (Jalloh, A.B, 2009).

### f) Basic and Alkaline Intrusions

Dolerite intrusions are common as dykes trending mainly E-W within the basement complex, and as extensive sills above the Rockel River Group. Kimberlite dykes and pipes which are alkaline intrusions follow a similar pattern in the east of the country. These pipes and dykes are the main hosts of the diamonds in the country.

The Freetown igneous complex is a basic layered complex that forms an intrusive body on the coast. It is composed of gabbro, norite, troctolite and anorthosite. Platinum occurs in the gravels of the streams that drain the complex. The relationship of this complex with other units is obscured by the coastal veneer of tertiary sediments.

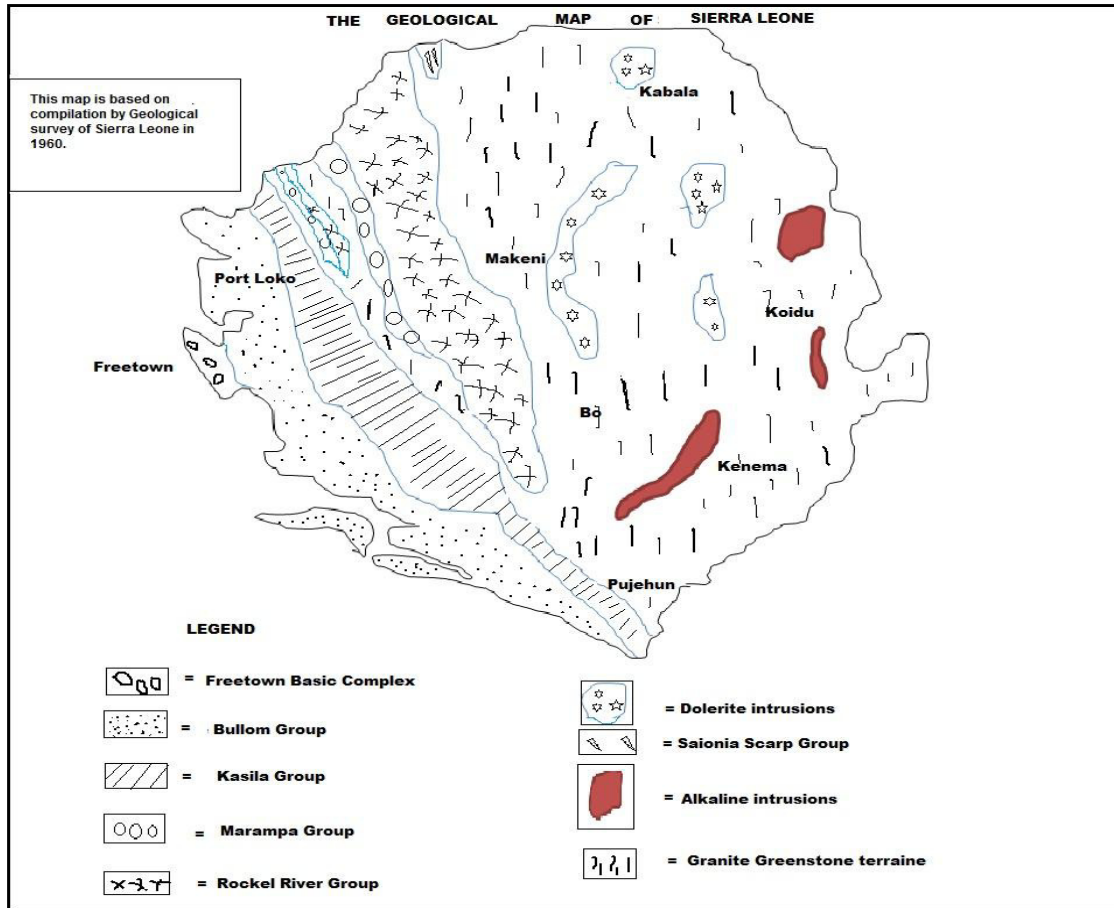


Fig 3 The Geological Map of Sierra Leone and its associated stratigraphy (Based on Dixey, F, 1925)

#### g) The Bullom Group

This group consists of mainly sediments and was formed as a result of the recent (tertiary) weathering and lateritization across a large part of the country, affecting mainly the greenstone belts and the dolerite intrusions. The bauxite deposits formed within the Kasila Group is a result of this weathering process.

### 3. MINING OF PRIMARY MINERALS IN SIERRA LEONE BEFORE AND AFTER THE CIVIL WAR

Organized mining in Sierra Leone began in 1927 after the Mineral Act was written and adopted. In the 1930's and 1940's significant mineral discoveries were made by the Geological Survey, notably iron ore at Marampa, alluvial diamonds in Kono, two extensive alluvial gold field deposits in the Sula Mountains and in the Kangari Hills, Placer gold in the Nimini Hills and the chromite deposit near Hangha in the Kambui hills. These deposits were developed into medium to moderate-sized mines.

#### 3.1. Diamond mining from 1930

Sierra Leone Selection Trust (SLST) began mining diamonds in Kono in 1930 and by 1951 cumulative production had exceeded 11Mct. SLST's annual production averaged 750,000 ct/yr from the mid1950's until the mid-1970's. In 1970, the government acquired a 51% interest and after 1975, exports declined to less than 0.3 Mct/yr and official exports dwindled to less than 10,000 ct during the civil war years (1991 to 2002). After the war, kimberlites, the main host rock for diamond have been discovered in Koidu and Tongo. The reserves are estimated at 6.3million carats at Koidu and 3.2 million carats at Tongo both to a depth of 600m.

Mining leases were granted to Rex mining Company and Branch Energy to exploit the kimberlite deposits. Branch Energy has transferred their lease at Koidu to Koidu Holdings S.A. which is currently producing 120,000 carats per year and they have plans to increase production because they have identified reserves to permit ongoing mining for at least another 15 years. They have finished exploring the Tongo dykes and they are now developing it into another producing mine. The search for other kimberlitic source rocks continues because not all alluvial diamond occurrences in the country could be linked with the known sources through alluvial dispersion.

### **3.2. Gold mining from 1930**

Gold was first discovered in the northern part of the country in 1926 and prospecting activities by the country's Geological Survey established the existence of gold in many other localities within the granite-greenstone terrain. Following the discovery of gold, several mining companies were involved in alluvial gold production. There was continuous but low mining from 1930 and stopped in 1956 due to the advent of the Alluvial Mining Scheme. However, mining resumed later, with production increasing in response to favorable market conditions reaching a peak annual production of 30,000 ounces in 1984. Exploration activities resumed in 2003, after the civil conflict and over 20 prospecting licenses were issued by the government. In 2008 Cluff Gold Limited submitted proposals for a mining lease in Baomahun. Recent results from Baomahun have already identified a mineral resource of over 1.1 million ounces of gold and a scoping study confirmed that an open pit mine could produce between 140,000 to 200,000 ounces annually.

Another company, Mano River Resources has three gold exploration concessions, which coincides with the richest areas for artisanal gold in the country. All three deposits are considered to have the potential to host gold deposits that are significantly larger than the deposits at Baomahun and Komahun which are the largest at the moment.

### **3.3. Bauxite mining from 1963**

Bauxite occurrence in Sierra Leone was first recorded in 1920 and 1921 at Falaba and Waia in the northern part of the country. Other bauxite occurrences included those between Moyamba and Mano which are weathered dolerite sills of the Rockel River Group, the Krim-Kpaka deposits in Pujehun District in the South; the Kamakwie and Makumre bauxite deposits in the North. The most important bauxite deposit finds were made by the Geological Survey in the Mokanji and Gbonge hills in 1960 and by SierraOre and Metal Company (SIEROMCO) in Port Loko in 1972. The Mokanji and Gbonge deposits in Moyamba district were mined by SIEROMCO from 1963 to 1995. The company was able to attain a maximum annual production of about 1.5 million tons.

Feasibility studies carried out by SIEROMCO on the Port Loko deposit indicated a mineable deposit with reserves of over 100 million tons out of which 77.3 million tons have been proved. The lease to explore, develop and possibly mine this deposit has been allocated to Gondwana Investments S.A.

The former bauxite mine owned by SIEROMCO has now been taken over by a new company; Sierra Minerals Holding and they commenced mining operations in March 2006 and have reported monthly production and export of up to June 2007. In 2006, they produced 1,071,059 mt. and in half a year in 2007, they produced 623,343 mt.

### **3.4. Iron Ore mining from 1933**

IronOre was discovered in the Marampa area in 1926.

In 1933, Sierra Leone Development Company (DELCO) started producing iron from Marampa till 1975 and closed as a result of liquidation. In 2005, London Mining Company (LMC) took over the Marampa concession and has developed it to a mining Project. The Tailings left by DELCO was reported at 45 million tons from 40 million at an average grade of 27.7% Fe and the primary ore was reported at 1 billion from 92 million at an average grade of 37.7% Fe. LMC started producing tailings and weathered ore to a consistent high quality in November 2011, and has produced as of May 2012, 300,000 dry metric tons of ore and shipped about 230,000 to Europe and China. This result has put the company in position to achieve their 2012 production target of 1.5Mt.

The other deposits investigated were the Tonkolili and Bagla Hill deposits. The Tonkolili iron deposit occurs in the Archaean Sula Mountain-Kangari Hills greenstone belt, close to Ferengbeya in the Northern part of the country. The iron occurs as residual or secondary ore caps resting on Precambrian banded iron formation. The caps are as a result of tropical weathering and leaching of underlying quartz-magnetite rocks and the iron rich amphibolites. Estimates



for the caps and primary ore are at least 720 million tons at an average grade of 56.3% Fe. African Mineral Limited (AML) have done an extensive drilling for resource modeling and has come up with an estimated reserve of 5 billion tons at an average grade 56.3% Fe and in late 2011 started exporting the cap to China. Annual export figures are not available yet at the Ministry. The Bagla Hill iron ore deposit occurs in the south eastern part of the country and it is a metamorphosed banded magnetite silicate rock made up of alternating layers of magnetite and quartzite. Preliminary evaluation done by Bethlehem Steel Company gave an ore reserve estimate of 384 million tons of primary ore (magnetite) at average grade of 18.1% Fe and about 90 million tons of haematite ore at 34.3% iron. Other minor occurrences are the Krim-Kpaka deposit in the south with 9 million tons at 40% iron and the Kukuna deposit in the north-west which is being currently developed by Cape Lambert Iron Ore Company with 15 million tons at 39% iron.

### 3.5. Rutile (TiO<sub>2</sub>) mining from 1967

Rutile was discovered in Sierra Leone in 1954 in the gravels of the Lanti River south of the Gbangbama region in the southern province. Four groups of deposits are known to be distributed around the country: the Gbangbama, Sembehun, Rotifunk and the Kambia deposit. Sierra Leone has the largest natural rutile reserve in the world.

The Gbangbama deposit consists of six major deposits: Mogbemo, Bamba-Pelebu, Pujubu, Lanti, Gbeni and Gangama. The first three deposits of the Gbangbama group have been almost completely exhausted. The Lanti deposit is currently being mined. At the end of 1994 the Gbangbama group had an estimate of 150 million tons of rutile at grade of 1.5 to 2% and also large reserves of ilmenite and zircon.

The Sembehun deposit is also made up of six deposits: Kibi, Dodo, Benduma, Komende, Mokamatipa and Matehun. Here exploration results in 1990, revealed the presence of over 180 million tons of rutile with grades ranging from 1.2 to 1.6% rutile.

The indicated resource estimate for the Rotifunk deposit in 1990 was 235 million tons at 0.62% rutile. The deposit consists of 6-7m thick horizon of sandy clay within the Bullom Group of sediments.

Sierra Rutile Limited (SRL), a subsidiary of Titanium Resources Group (TRG) is the sole operating company in the country now and was the largest producer of natural rutile, accounting for about one quarter of global output before its rutile mine was shut down in 1995. The company began to rehabilitate in 2005 and after a ten year gap due to the rebel war, began production and exporting in 2006. Rutile production in 2006 and 2007 are as follows: in 2006, 73,803 million tons were produced and in a half year in 2007, 42,005 tons were produced.

## 4. DISCUSSION AND RECOMMENDATIONS

While the resurgence of the Sierra Leonean mining sector has been impressive since the civil war, it has so far focused on the re-establishment of closed mines and the exploitation of previously proven reserves. However, the greatest challenge in the immediate post-conflict situation still remains on how to retain foreign investments in the mining and mineral sector. This requires measures to create the enabling environment for such investment that succeeded in re-opening the rutile, bauxite, gold, diamond and iron ore operations. Recognizing the need to create or establish an enabling environment for attracting and retaining new investments into the mineral exploration development and exploitation, new mining policies were incorporated into the Mines and Mineral Acts of 2007.

With the successful implementation of the International Monetary Fund (IMF) supported economic reform program, which has established a sound macroeconomic environment that has kept inflation under control and also the introduction and implementation of the Kimberley process, which has facilitated the export of diamonds through official channels, the domestic mining sector will once again underpin the economy and support the government's developmental objectives.

Here are a few recommendations proposed to both the present and prospective governments on how to utilize the revenue that is generated from the mining sector to help in the development of the nation and to alleviate poverty and also to lessen the country's dependence on foreign aid.

- 1) The strong global demand for minerals, underpinned by rapid growth in emerging economies such as China, India and Brazil has fuelled an investment boom in the mining sector in the country. Therefore revenues generated from this sector should be used to help improve the agricultural sector. Government should take a systematic approach to ensure that they provide the infrastructure, prioritize and pump in a lot of resources into Agricultural Education and extension projects. Those endeavouring in that domain must be encouraged by additionally subsidizing their

education and enterprise. Added incentive in the form of free agricultural education, ready employment and market will help. Massive overhaul of current methods using trained manpower, modern technology are imperative if this sector is to move from subsistence level to a mechanized level. Mechanization and improved technology is the key to food security.

- 2) With surface and groundwater potential, funds generated from the mining sector should be used to develop surface water treatment plants to provide pipe water to the population both in urban and rural areas.
- 3) Government should partner with the mining companies to establish tertiary research institutions that will be of mutual benefit to both the nation and the companies as well.
- 4) The fund should be used to explore the possibility of harnessing nature like wind, solar, hydropower and biomass for the development of renewable energy for electricity supply which is a must if the country is to attain an industrial status.

## 5. CONCLUSION

Notwithstanding its relatively small size, Sierra Leone is widely recognized as a highly prospective target for mining activities. Currently five major companies which London Mining Company Limited, African Minerals, Sierra Rutile, Koidu Holdings S.A and Cluff Gold Limited are all extracting these resources plus a dozen of others prospecting

The return to political stability in the country coupled with positive global developments in the mining sector has rejuvenated the domestic mining sector. The rejuvenation of this domestic mining sector after the war shows that Sierra Leone will be able to look after itself in the future. From present research point of view, the following conclusions are drawn;

1. With all the mineral resources available in Sierra Leone, the country is still one of the poorest nations in sub-Saharan Africa.
2. Despite the strong rebound of the mining sector in recent years, its contribution to public revenues remains weak to support the nation's sustainability.
3. The country is endowed with a large natural resource base, not only minerals, but also agriculture, and marine fishing. In times of peace agriculture contributed about 50% of the GDP with coffee and cocoa been the main principal export crops, whereas prior to 1991, the mineral industry generated only between 18 and 20% of the GDP, with rutile, bauxite, diamonds and gold being the main export mineral commodities.
4. The civil war had impacts on the mining sector yes but this sector had been in operation for more than 20 years before the civil war and as seen Iron Ore production had ceased long before the war.
5. Four recommendations have been proposed on how current and prospective governments will achieve their objectives by utilizing the revenues from mineral industries.

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