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# Geological mapping of Sierra Leone: baseline assessment and next steps

BGS Global

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National Minerals Agency NMA

Petroleum Directorate Sierra Leone

FOURAH BAY COLLEGE
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OPEN REPORT OR/18/004

# Geological mapping of Sierra Leone: baseline assessment and next steps

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The group involved in the geological reconnaissance fieldtrip across Sierra Leone, January 2018

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As part of our field reconnaissance in 2018 we were generously welcomed at several mines and exploration projects, by organisations including SL Mining Ltd, Koidu Limited, Meya Mining, Allotropes Diamond Ltd, and Sierra Rutile (Iluka Resources). Unfortunately time constraints meant that we were unable to reach Blue Horizon Ltd (African Battery Metals) or Sierra Minerals Ltd (Vimetco). The AMR Gold licence in the Loko Hills was visited as part of a separate trip in 2017. All these organisations are greatly thanked for their assistance in allowing us to visit their mine sites and view core material. Joseph Lebbie, Chief Geologist, and Prince Cuffey, Director of Geological Survey, both at the National Minerals Agency, are particularly thanked for their assistance in planning and organising the field reconnaissance.

# Contents

# 1 Introduction

Sierra Leone is a resource-rich country, with extensive known and potential mineral and petroleum resources. However, knowledge about the geology of the country is limited, with very little modern data in the public domain, and this hinders sustainable development of these resources for the national good. The lack of data is now being addressed by the Extractive Industries Technical Assistance Programme Phase 2 (EITAP 2) which is funded by the World Bank, and which aims to deliver a national airborne geophysical survey and subsequent geological mapping of the country (World Bank, 2017).

Alongside EITAP 2, the UK government is funding the British Geological Survey (BGS) to work in partnership with relevant institutions in Sierra Leone, including the National Minerals Agency (NMA), the Petroleum Directorate (PD) and Fourah Bay College (FBC), to build their capacity to collect, manage and disseminate geological data. As part of that work, a field reconnaissance was carried out across Sierra Leone in January 2018 to assess the state of current geological mapping, visit mines and exploration projects,  and to discuss how best to plan and carry out a mapping programme. The field trip was led by three British Geological Survey (BGS) staff members (Kathryn Goodenough, Jon Ford, and Darren Jones) together with 11 geologists from the NMA, two geologists from the PD, and two staff members from the Geology Department at Fourah Bay College. Pauline Scott and Avril Jamieson from the Department for International Development (DFID) joined the first two days of the trip.

This report describes the conclusions arising from that field reconnaissance and associated literature review, including a baseline assessment of the current geological mapping of Sierra Leone, and suggestions for next steps. Some information is also derived from separate field visits to the AMR Gold licence area in the Loko Hills (April 2017) and coastal outcrops in the Lungi area (June 2017).

Areas visited during the January 2018 reconnaissance are listed below:

Day 1: Freetown to Makeni and visit to the Marampa mine site.

Day 2: Makeni to Batkanu, on to Port Loko and return to Makeni

Day 3: Makeni to Kabala

Day 4: Around the northern part of the Sula Mountains

Day 5: Makeni to Koidu

Day 6: Rest morning, afternoon at Koidu Ltd

Day 7: Morning at Meya Mining, afternoon drive to Kenema

Day 8: Kambui Hills and geology around Kenema.

Day 9: Outcrops at Bo and visit to Allotropes Diamonds to see core, drive to Sierra Rutile

Day 10: Morning at Sierra Rutile and return to Freetown.

# 2 Overview of current geological mapping of Sierra Leone

The bedrock geology of the north-eastern half of Sierra Leone is dominated by Archaean basement, belonging to the Kenema-Man Archaean domain of the West African craton (Rollinson, 2016). Within this basement a number of distinct supracrustal belts have been mapped, as well as a series of late-Archaean granitoids (Rollinson, 2016). The western margin of the craton in Sierra Leone is marked by a Pan-African deformation zone known as the Rokelides (De Waele et al., 2015) and a strip of Palaeoproterozoic gneiss, the Kasila Group (Williams, 1988), which has been accreted to the craton. The craton margin is unconformably overlain by two metamorphosed volcanosedimentary successions, the Marampa and Rokel River groups. Mesozoic mafic intrusions, associated with the continental rifting and opening of the Atlantic, are present throughout much of Sierra Leone; the most significant of these, the Freetown Complex, underlies the capital city. The youngest lithostratigraphic group is the Bullom Group, comprising onshore Cenozoic sediments deposited along the coastal margin. Superficial geology includes river terraces and alluvium that are locally associated with artisanal diamond and gold mining, and a coastal belt comprising marine and estuarine sediments.

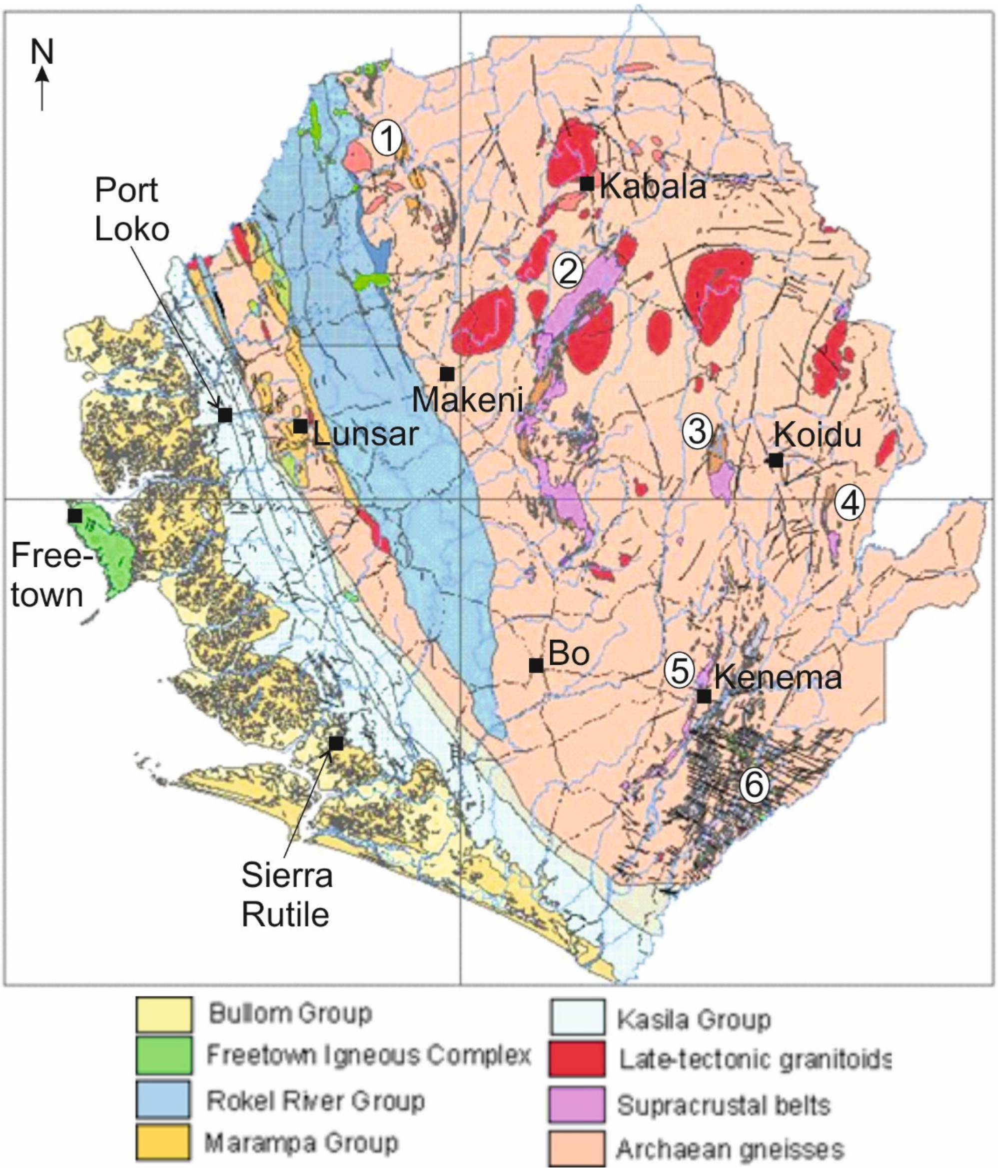


**Figure 1: Simplified geological map of Sierra Leone, derived from the national map (CGS, 2004), © National Minerals Agency. Major lithologies indicated in key. The width of the country is c. 250 km, from the most easterly to most westerly point. Numbers indicate supracrustal belts, as in section 3.7.2**

Most work on natural resources in Sierra Leone depends upon the 1:250,000 national geological map of Sierra Leone, which was compiled in 2004 by the Council for Geosciences for the Geological Survey of Sierra Leone (CGS, 2004). This map is now often treated as being accurate, despite the fact that it has clear shortcomings. Production of the map appears to have involved collation of existing data, possibly with some interpretation of aerial photographs, but no ground-truthing or additional primary data collection. The main data sources (Figure 2) included previous BGS geological mapping of the northern third of the country, carried out during the 1970s (MacFarlane et al., 1981), and mapping carried out by the Geological Survey of Sierra Leone (GSSL) from the 1950s to the 1970s, only some of which has been published (Wilson and Marmo, 1958; Mackenzie, 1961; Marmo, 1962; Wilson, 1965; Andrews-Jones, 1966; Hall, 1968). The published maps included a significant amount of observational detail, some of which was transferred to the CGS (2004) map, although not all the detail was included. In contrast, there are other areas of the country in which the geology has never been mapped, and which lack any real information. The CGS (2004) map is thus very inconsistent in level of detail, and gives a false impression that some areas contain no geological interest, when in fact they simply lack appropriate mapping: the simplicity of the map in these regions is due to absence of evidence, rather than any lack of geological features. In general, there is potential for significant updating of the CGS (2004) map to include a consistent level of detail across the whole country, including a much more consistent classification of the rock units present within Sierra Leone.

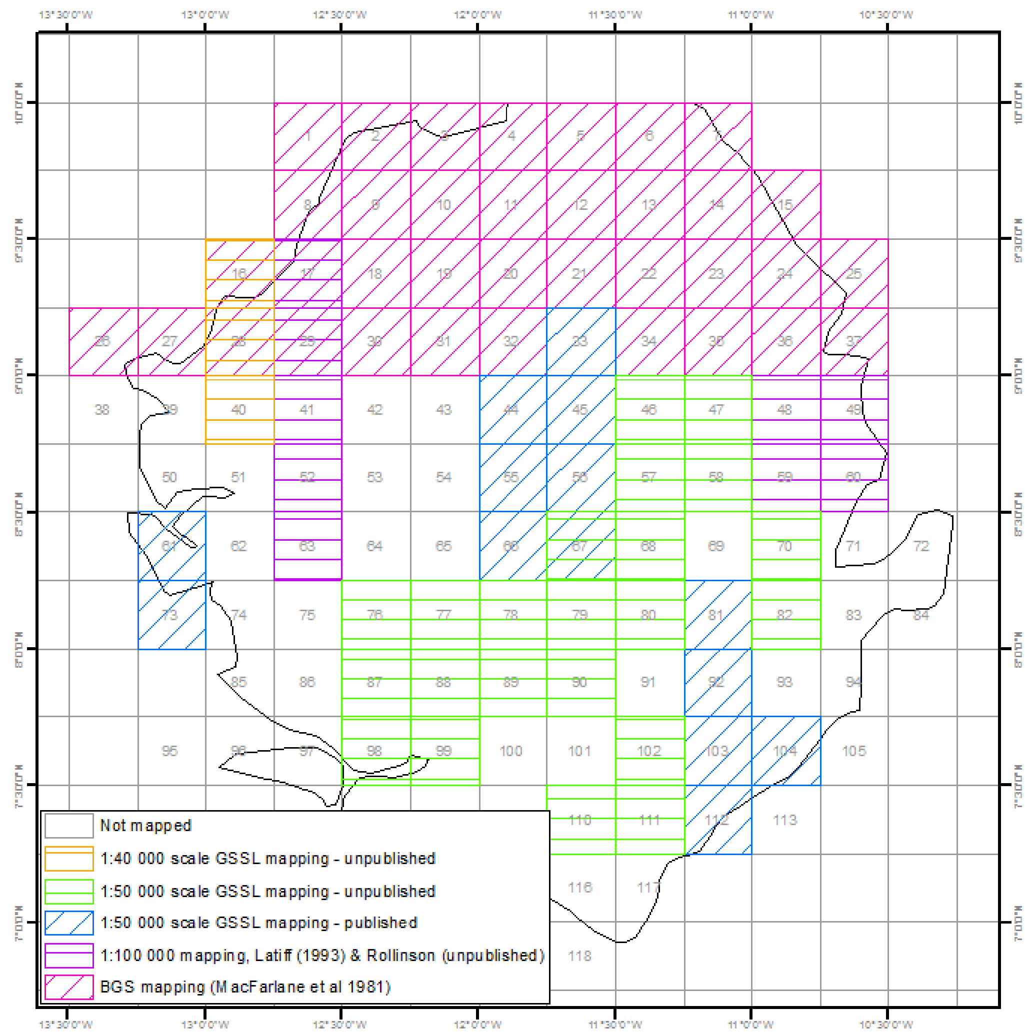


**Figure 2: Existing geological mapping of Sierra Leone. Some of the maps shown as unpublished are no longer readily available.**

The landscape of Sierra Leone has been extensively affected by tropical weathering, and so natural outcrops are largely confined to river valleys and coastal sections; however, numerous quarries and road cuts provide valuable exposures. Significant amounts of core have been collected during exploration for mineral resources, and where this core material can be studied it will provide valuable additional information for map revision.

In order to develop a modern geological map of Sierra Leone, several important aspects should be addressed. As well as the planned airborne geophysical survey, all available remote sensing data should be gathered. Some remotely sensed data are widely available, for example satellite imagery from USGS Earth Explorer (https://earthexplorer.usgs.gov/) and digital elevation data from NASA (https://www2.jpl.nasa.gov/srtm/). All existing maps, including those in published papers and PhD theses (where available) should be scanned, georeferenced, and compiled into GIS. Existing published data and information on the geology of Sierra Leone are summarised in the sections below. The NMA already holds many of these maps (and associated bulletins and reports) but they have yet to be consistently georeferenced and stored in a common format. One key objective will be the set-up of a geological dictionary which should include the list of geological units to be mapped, with descriptions for each. Whilst undoubtedly changes and additions will need to be made during new mapping, it is important that any new mapping is done against a coherent list of unit names, and that appropriate data management procedures are followed. Similarly, a clear list of map symbols to be used should be developed, following international standards – a list of the symbols used by BGS will be provided to the NMA. New mapping should be collated in a GIS format to be stored in the GIMS.

# 3 Mapping of individual units

This section summarises the state of knowledge on each of the major lithostratigraphic units currently identified within Sierra Leone, working broadly from youngest to oldest, and suggests possible approaches for improving the baseline geological mapping of the units.

## 3.1 BULLOM GROUP

The Bullom Group is the youngest recognised stratigraphic group in the country, and comprises poorly consolidated Cenozoic sediments which outcrop along the coastal strip of Sierra Leone. It rests unconformably on the older rocks of the Kasila Group and the Freetown Complex. There has been very little detailed work on the Bullom Group, which was described by MacFarlane et al. (1981) as comprising poorly consolidated, coarse quartzofeldspathic sands interbedded with seams of clay, clay-sand and lignite. Mackenzie (1961) described a single natural section at Kambalo on the River Jong, in which c. 6 m of sands and gravels (the Jong sands) overlie another c. 6 m of pale-coloured kaolinitic sand and clay. The Bullom Group is well-exposed along the coastal cliff section between Lungi Town and Konakridie. Here a 20-25 m high cliff face has a 5-10 m exposure of the Bullom Group at the base, overlain by a deep laterite weathering profile (Figure 3).

The Bullom Group is particularly important due to its localised concentrations of heavy minerals, which are mined by Sierra Rutile in one of Sierra Leone’s largest mines. Exposures around the mine show immature gravels and sands, with angular clasts in some areas up to 20 cm across, broadly overlying sand and clay (Figure 3). The upper sands and gravels represent the part of the Group which is richest in rutile. The Bullom Group also has the potential to be important as an aquifer for groundwater, and as an onshore analogue may help in understanding the sediment provinces for the Cretaceous sedimentary units offshore that are prospective for hydrocarbons. No formal stratigraphy for the Bullom Group has been set up, and a compilation of all available information would be valuable to understand the history and depositional conditions of this unit. Due to the limited natural exposures, drilling a number of shallow boreholes through the Bullom Group should be considered as part of any mapping programme.

**Figure 3: Studying exposures in the Bullom Group a) in the Sierra Rutile licence area and b) at Konakridie**

## 3.2 MESOZOIC MAGMATISM

### 3.2.1 Kimberlites

Mesozoic (Triassic to Jurassic?) kimberlites are exposed in the area around Koidu in eastern Sierra Leone. This area contains three kimberlite pipes up to 300 m across and a swarm of kimberlite dykes, typically running ENE-WSW and <5m wide (Hall, 1968; Tompkins and Haggerty, 1984). A second swarm of kimberlite dykes, with ENE-WSW trend, occurs in the Tongo area (Hall, 1968). These dyke swarms are laterally extensive over several kilometres. Alluvial diamond fields are also known in many areas of Sierra Leone, both close to the known kimberlites, and at a greater distance from them (Hall, 1968; Thomas et al., 1985). Due to the importance of diamonds for Sierra Leone's economy, attention should be paid to identification and mapping of both the kimberlites and the alluvial sediments, including river terrace deposits.

### 3.2.2 Doleritic dykes

Mesozoic dolerite-gabbro dykes, formed during the opening of the Atlantic in this region, are mapped in great detail in the Gola Forests area in the SE of the country (Wilson, 1965) but have not been mapped elsewhere. However, they certainly do exist elsewhere, particularly along the parts of the country closer to the coast. Mapping of these dykes should be made more consistent across the country, as they are important for hard-rock quarrying, for their effect on infrastructure, and for their role in forming geomorphological traps for diamond and other mineral placers. Mapping of dykes will likely be achievable by the use of remote sensing, with local ground-truthing.

### 3.2.3 The Freetown Complex and other intrusive complexes

The Freetown Complex is a moderately well-exposed mafic layered igneous complex forming the mountains on which the city of Freetown is built. It is dated at c. 202 Ma, i.e. end-Triassic (Callegaro et al., 2017). It has been studied in some detail by a number of authors, both for its igneous history (Wells, 1962; Umeji, 1975; Umeji, 1983; Chalokwu et al., 1999; Chalokwu, 2001; Chalokwu and Seney, 2009) and for its potential for platinum-group element resources (Bowles, 1988; Bowles et al., 1994; Bowles et al., 2013). Recent landslide events have demonstrated the importance of understanding features such as fractures and other discontinuities within the Freetown Complex, which may be of importance for geohazards and infrastructure. Compilation of all existing maps and data for the Freetown Complex should be undertaken as a matter of priority, and consideration should be given to acquisition of remote sensing data such as LIDAR.

Alkaline complexes that may be of similar age to the Freetown Complex are also known from Sierra Leone. About 35 km ESE of Freetown, at Songo Town, small outcrops of the nephelinerich rock ijolite have been identified and shown to form a small intrusive stock (Baker et al., 1957). In the Gola Forest, the Bagbe Complex is a larger igneous intrusion comprising alkaline granitic and syenitic lithologies (Wilson, 1965). These alkaline intrusive rocks have the potential for resources of critical metals such as the rare earth elements and niobium, therefore further study of these localities is recommended.

### 3.3 THE SAIONIA SCARP GROUP

The Saionia Scarp Group of northern Sierra Leone is a sedimentary succession that rests unconformably upon the underlying Rokel River Group and Archaean basement. It has been divided into two formations: the lower Moria Formation and the upper Waterfall Formation (Reid and Tucker, 1972). The Waterfall Formation contains sedimentary rocks considered to be of glacial origin, and of late Ordovician age (Tucker and Reid, 1973). The Saionia Scarp Group was not visited as part of the field reconnaissance.

### 3.4 THE ROKEL RIVER GROUP

The Rokel River Group is a volcanosedimentary succession, metamorphosed to low grade, which was described in some detail by MacFarlane et al. (1981) and is relatively well-exposed in the northern part of its outcrop, chiefly in river exposures. It has also been studied by Allen (1968), Culver and Williams (1979) and Latiff et al. (1997), and has been divided into 4 formations (Figure 4). It rests unconformably upon the Marampa Group and the basement gneisses. Allotropes Diamonds kindly provided access to some core material through the Rokel River Group, which has transected this basement unconformity and clearly shows the relationship. Away from the rivers, rocks of this group typically form flat laterite plains with no exposures seen during this reconnaissance trip. Any update to the mapping of this group will be best achieved by river traverses at the lowest water levels possible. However, it seems likely that compilation of the existing mapping will offer the most information about the Rokel River Group.

### 3.5 THE MARAMPA GROUP

The Marampa Group is a Neoproterozoic, volcanosedimentary succession (De Waele et al., 2015) which crops out in a discontinuous strip along the eastern side of the Rokel River Basin. It has been described by MacFarlane et al. (1981) who divided it into two formations: a lower Matoto Formation, including mafic volcanics and ultramafic units; and an upper Rokotolon Formation dominated by metasedimentary rocks. The Marampa Group was subsequently mapped by Latiff (1993) and the Rokotolon Formation was further divided into three Members (Latiff et al., 1997) (Figure 4). The Marampa Group is well-exposed in the Mabole, Little Scarcies, and Great Scarcies river sections (MacFarlane et al., 1981). The Rokotolon Formation can be studied in exposures around the hill of the same name, including exposures in the Batkanu – Port Loko road, and the Massaboin Member is also well-exposed in old pits where it has been mined for iron at the Marampa mine near Lunsar (Figure 5). The highly sheared contact with the Archaean gneisses is exposed near Lunsar (Latiff et al., 1997). Extensive core through the group is preserved at the Marampa mine core shed. There may be potential to improve the mapping of the Marampa Group in the area south of that mapped by MacFarlane et al. (1981), particularly where new exposures have been opened up by mining.

<table>
<tr><th colspan="2">Formation/ Member</th><th>Rock type</th></tr>
<tr><td colspan="3">ROKEL RIVER GROUP</td></tr>
<tr><td colspan="2">Taia Formation</td><td>Shale and feldspathic sandstone</td></tr>
<tr><td colspan="2">Kasewe Hill Formation (200m)</td><td>Andesitic to dacitic lava and tuff</td></tr>
<tr><td colspan="2">Teye Formation (200m)</td><td>Silty shale with quartzite bands</td></tr>
<tr><td colspan="2">Tabe-Makani Formation (180m)</td><td>Basal polymict conglomerate (tillite) and thin shaly sandstone</td></tr>
<tr><td colspan="3">MARAMPA GROUP</td></tr>
<tr><td rowspan="3">Rokotolon Formation</td><td>Massaboin Member (150m)</td><td>Quartz-haematite schist</td></tr>
<tr><td>Masimera Member (350-450m)</td><td>Semi-pelitic schist</td></tr>
<tr><td>Mabla Member (2-90m)</td><td>Orthoquartzite</td></tr>
<tr><td colspan="2">Matoto Formation (250-300m)</td><td>Metavolcanics and ultramafic rocks</td></tr>
</table>

**Figure 4: The stratigraphy of the Marampa and Rokel River groups, after Latiff et al. (1997)**

## 3.6 THE KASILA GROUP

The Kasila Group is a NW-SE trending strip of highly deformed and metamorphosed amphibolite- to granulite-facies metasedimentary and meta-igneous rocks of Palaeoproterozoic age (De Waele et al., 2015). It forms the westernmost part of Sierra Leone's basement, and was likely accreted to the margin of the West African Craton during the Pan-African Orogeny, at the end of the Neoproterozoic (Villeneuve, 2008). Its western contact is entirely covered by Bullom Group sediments, and its eastern contact is recorded as a mylonite zone several km in width (MacFarlane et al., 1981). It is broadly divided into an eastern part which comprises dominantly granulite-facies rocks, mostly metabasic with subordinate metasedimentary lithologies, and a western portion of amphibolites and metasedimentary migmatites and gneisses (Williams, 1988). Leucogabbroic units within the eastern part of the Kasila Group are the main protoliths for Sierra Leone's bauxite resources (Williams, 1988).

The Kasila Group is generally not well exposed, but can be studied in a number of quarries including two visited on this trip, one in the Ocara Hills on the Makeni-Freetown Highway (Figure 5) and one close to Rogberi Junction between Lunsar and Port Loko. In the Gbangbama Hills, adjacent to the Sierra Rutile mine, natural exposures of both amphibolite- and granulite-facies gneisses can be found (Mackenzie, 1961) and were visited during the January 2018 field trip. Away from the hilly areas, the best exposures are likely to be found in quarries and river valleys. Allotropes Diamonds also hold some core material through the Kasila Group.

The CGS (2004) map divides the Kasila Group into two successions, the Magbele and Tapr, although the brief descriptions of these successions on the map legend are very similar. The basis for this subdivision is not clear; it may be based on unpublished Geological Survey reports. In general, the Kasila Group is poorly understood. The Kasila Group represents the source rock for Sierra Leone's bauxite and rutile resources, as well as being an area with potential for other metallic mineralisation. Remapping should pay particular attention to the structural and metamorphic history, which is likely to be of importance for exploration targeting.

**Figure 5: Examples of folding in a) the Kasila Group in the Ocara Hills and b) the Marampa Group at the Marampa Mine**

## 3.7 ARCHAEAN BASEMENT

A synthesis of the Archaean basement of Sierra Leone has recently been provided by Rollinson (2016), and descriptions were given by Williams (1978) and MacFarlane et al. (1981). Archaean basement gneisses underlie much of eastern Sierra Leone, and also crop out to the west of the younger Rokel River and Marampa groups. The western strip of exposure has been termed the Kenema Assemblage (De Waele et al., 2015); it is likely to be continuous with the main area of Archaean basement, and to lie beneath the overlying Rokel River and Marampa groups.

The Archaean basement comprises three broad units (Rollinson, 2016): 1) the basement gneisses, 2) the supracrustal belts, and 3) the late-tectonic granitoids. Previous work (MacFarlane et al., 1981) had proposed that two major cycles of Archaean crustal formation could be recognised (the Leonian and Liberian) on the basis of structural relationships observed in the field. More recently. modern geochronology has thrown doubt on the existence of two distinct cycles (De Waele et al., 2015; Rollinson, 2016), suggesting a more complex history of crustal growth, deformation and metamorphism that would be challenging to map-out nationwide on the basis of outcrops available in Sierra Leone.

### 3.7.1 Basement gneisses

The Archaean basement is dominated by banded biotite gneisses (Rollinson, 2016) with some areas of pyroxene and hornblende bearing gneiss (indicating granulite and amphibolite facies). The majority of the gneisses are felsic in composition, but more mafic to ultramafic bodies (dominated by amphibolites) form masses a few centimetres to a few metres in size within the gneisses (MacFarlane et al., 1981). Migmatitic textures are common, with abundant sheets and veins of granite and granitic pegmatite cutting the gneissose banding. In shear zones, such as those which bound the Sula Mountains Belt, these veins and sheets are deformed. The presence of these extensive granitic veins makes the basement gneisses of Sierra Leone unusually potassic in their average composition, compared with many other cratons (Rollinson, 2018).

MacFarlane et al. (1981) identified a number of lithological subdivisions in the northern part of Sierra Leone, separating out a number of types of ‘migmatitic gneiss’ and ‘porphyroblastic gneiss’. Many of these subdivisions grade into each other over some distance, without mapped boundaries, and it would be challenging to extend the subdivisions across the whole country. Wilson (1965) used a different set of subdivisions within the basement when mapping the Gola Forests area in the south-eastern part of the country, separating ‘hybrid rocks and migmatites’ from ‘enderbites’, giving an appearance of extensive detail in this part of the map. These subdivisions were partly based on a hypothesis of 'granitisation', which is not consistent with modern understanding of basement gneisses. As with the subdivisions in the north, it is unlikely to be appropriate to extend the units mapped by Wilson (1965) across the country.

In view of the constraints on a nationwide geological survey, it is recommended that new maps of the country treat the Archaean TTG gneisses as a single lithological unit, unless any clear subdivisions are recognised during the mapping that can be mapped across the whole country. The focus should be on mapping structural features such as shear zones, identifying regional variations in metamorphic grade, and mapping out the supracrustal belts and late-tectonic granitoids (below). The objective should be a consistent approach to mapping of these rocks across the whole country, rather than showing potentially misleading detail in particular areas.

### 3.7.2 Archaean supracrustal belts

1. Loko Hills

The rocks of the Loko Hills supracrustal belt were described and mapped by MacFarlane et al. (1981) and the area was visited by a BGS-NMA team in 2017. The supracrustal belt comprises several isolated masses, described by MacFarlane et al. (1981) as forming hilltops; contacts with the surrounding gneisses are rarely exposed. Lithologies of the Loko Hills include amphibolites, quartzites, semi-pelitic gneisses and banded ironstones. Garnet-sillimanite assemblages are recorded in some of the semi-pelitic gneisses, consistent with metamorphism to amphibolite facies. Recent exploration by AMR Gold has proved the existence of several late-tectonic granitic and pegmatitic intrusions intruding the Loko Hills supracrustal rocks, of which some are enriched in tantalum (as coltan) and others are enriched in lithium (as spodumene). Late-tectonic granitoids (see below) are also common around the margins of the supracrustal belt. Gold mineralisation is known in the area from the presence of extensive artisanal mining around Laminaia (MacFarlane et al., 1981), and AMR Gold hold core through the supracrustal rocks in this area.

2. Sula Mountains

The geology of the Sula Mountains-Kangari Hills has been described in detail by Wilson and Marmo (1958), Marmo (1962), MacFarlane et al. (1981) and Rollinson (1999). The Sula Mountains supracrustal belt forms the broadly NE-SW trending ranges of the Sula Mountains and Kangari Hills, an area of relatively rugged topography in which outcrops are sparse, due to very heavy weathering on the hillslopes (Davies et al., 1989); good exposures can be found in stream sections and road cuttings (Rollinson, 1999). The rocks of the northern part of the supracrustal belt are divided into two formations: an older Sonfon Formation which comprises mafic to ultramafic metavolcanic rocks including amphibolites and serpentinites, and the younger Tonkolili Formation which is dominated by metasedimentary rocks including banded iron formations (MacFarlane et al., 1981).

Previous work suggested that the supracrustal rocks of the Sula Mountains may lie unconformably on the surrounding gneisses (MacFarlane et al., 1981) although no exposures of the unconformity were found. However, our reconnaissance visit indicated that the Sula Mountains supracrustal belt is likely bounded on both sides by NE-SW trending shear zones, which are not shown in detail on existing maps. Exposures of highly sheared gneisses can be seen at Dondoya at the north-eastern end of the supracrustal belt outcrop. A major shear zone is also described as separating the Sula and Kangari parts of the supracrustal belt (Barrie and Touret, 1999). Mapping of these shear zones should be considered as a priority, not least because of the likelihood that such major structures exert a control on mineralisation.

Gold mineralisation is well-known from the Sula Mountains supracrustal belt and extensive gold has been produced from alluvial deposits in the Lake Sonfon-Dalakuru area (MacFarlane et al., 1981). Primary lode gold mineralisation has also been recognised at a number of localities and at Yirisen, the gold occurs in aplitic-sericitic quartz veins that cut sheared and strongly altered schists of the supracrustal belt (Barrie and Touret, 1999). The Sula Mountains are also important for deposits of iron ore within the Tonkolili Formation, and the Tonkolili mine (Shandong Iron and Steel) is one of Sierra Leone's major mines. Pegmatites have also been recorded within the Sula Mountains supracrustal belt, but not studied in detail.

Core through the supracrustal belt is now available at the Blue Horizon (African Battery Metals) Ferensola project where drilling was carried out in 2017, and may provide information to refine existing understanding of this supracrustal belt. The existing detailed lithological mapping is considered likely to be broadly fit for purpose, and any new mapping should focus on the structural geology and mineralisation of this supracrustal belt.

3. Nimini Hills

The stratigraphy of the Nimini Hills supracrustal belt is divided into a lower, mafic-ultramafic formation dominated by amphibolites, and an upper metasedimentary formation dominated by metasandstones with minor quartzite and banded iron formation (Rollinson, 1983). This stratigraphy is indicated on the CGS (2004) map. Lode gold is known to occur at Komahun in the Nimini Hills, at the contact between pelite and ultramafic schist (Rollinson, 2016). The Nimini Hills were not visited during the field reconnaissance trip.

4. Gori Hills

The Gori Hills have similar stratigraphy to the Nimini Hills, with mafic-ultramafic metavolcanic rocks overlain by a metasedimentary formation (Rollinson, 1983). The metasedimentary rocks in the northern part of the Gori Hills are marked by significant facies variations, with pelitic schists passing laterally into quartzites over a distance of around 3 km (Rollinson, 1983). The Gori Hills were not visited during the field reconnaissance trip.

5. Kambui Hills

The geology of the Kambui Hills supracrustal belt was described by Andrews-Jones (1966). It is dominated by mafic-ultramafic rocks with a zone of interbanded serpentinised dunite and chromite that has been mined in the past for chromite. Smaller areas of metasedimentary rocks include biotite gneiss, quartzite and banded iron formation. The detailed 1:50,000 lithological mapping (Andrews-Jones, 1966), which has not been included in the CGS (2004) map, is likely fit for purpose; as with the Sula Mountains, any new mapping should focus on structural issues.

6. Mano Moa granulites

The highly disrupted Mano Moa granulites contrast with all the other greenstone belts of Sierra Leone in preserving granulite-facies assemblages (Andrews-Jones, 1966; Rollinson, 1982). They comprise abundant lenses of quartzite, banded iron formation, and other metasedimentary and meta-igneous lithologies intercalated within the basement gneisses (Andrews-Jones, 1966). Although the lithologies in this area have been mapped in some detail, their structural context is poorly understood, and should be a focus for new mapping.

### 3.7.3 Late-tectonic granitoids

The youngest lithologies in the Archaean basement are late-tectonic granitoids which were mapped in the northern part of Sierra Leone by MacFarlane et al. (1981) and have been described by Rollinson (2016). These are large intrusions, commonly several kilometres to tens of kilometres across, of coarse-grained granitoid rocks. They vary from medium-grained biotite granite to very coarse-grained granite with microcline phenocrysts (Rollinson, 2016). They may be massive and structureless, or may show a relatively weak foliation typically defined by aligned biotites. These granitoids typically form large rounded hills, slabby outcrops and rounded boulders, and thus can be recognised by their distinct topography. In the north, they have been accurately mapped by MacFarlane et al. (1981) but to the south of that area they are not indicated on the CGS (2004) map, despite ‘late-kinematic granitoids’ having been recognised by the GSSL (Marmo, 1962; Andrews-Jones, 1966). Some unmapped late-tectonic granitoid intrusions were recognised during the reconnaissance fieldtrip, particularly the southwestern extension of the Gbengbe hills granitoid around Makeni (well exposed in a quarry just west of Makeni on the Freetown road) and a large granitoid body on the road from Makeni to Koidu between the Kangari and Nimini Hills supracrustal belts. Around Koidu, coarse-grained hornblende granodiorite forms the host rock for the kimberlites that are being mined, and likely represents another mappable late-tectonic granitoid body.

Clearly, any new geological mapping should aim to accurately and consistently record the extent of these late-tectonic granitoids across the country. Also of importance is modern geochronological dating of these granitoids; they are currently considered to be c. 2800 Ma on the basis of dating in the eastern part of the craton (Rollinson, 2016). It is possible that some of Sierra Leone’s late-tectonic granitoids, particularly near the craton margin, could in fact be Pan-African in age (in the range 550-650 Ma).

**Figure 6: Massive to weakly foliated late-tectonic granitoids in the quarry at Makeni, contrasting with strongly foliated and folded Archaean TTG gneisses from the Loko Hills**

# 4 Priority areas for further work

Any final decisions on priority areas for geological mapping should be made in the context of the forthcoming nationwide airborne geophysical survey. Combination of this survey with geological mapping at 1:100,000 or ideally 1:50,000 scale (World Bank, 2017) should allow development of an improved national map. Within this map, features such as late-tectonic granitoids and Mesozoic dykes should be mapped and represented in a consistent way across the country. It is evident that there is a need for more detailed understanding of large-scale structures across Sierra Leone, including major shear zones that may host mineralisation of a range of ages, and these areas should be targeted with more detailed investigation. Areas of particular interest include the supracrustal belts within the Archaean basement, and the Kasila Group. In the coastal strip, both the Bullom Group and the Freetown Complex deserve further attention due to the importance of this area for natural hazards, mineral and energy resources, groundwater and urbanisation. Any new mapping should be supported by appropriate data standards, management procedures and infrastructure to ensure its consistent capture and effective delivery.

# 5 Conclusions

This report provides a brief overview of the current state of geological knowledge in Sierra Leone. It is evident that baseline geological knowledge is highly variable across the country; some areas have been mapped in detail whilst others have not been mapped at all, and the existing maps are inconsistent in many respects. Most of the country completely lacks any modern description of geological structures or synthesis of known mineralisation. Modern geochronological information is also lacking, particularly in the basement supracrustal belts and late-tectonic granitoids, and in the Kasila Group. Sierra Leone is clearly in need of modern, nationwide geological mapping that follows international best practice with regard to naming of lithological units and identification of structural features.

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