Geology and Mineral Industry of Sierra Leone

(Geologic Country Report with Emphasis on Diamonds, Gold, and Titanium)

1st July 2011

(Dr. J.M. Warnsloh, J.M.W. Geo-Consulting)

Table of Contents

1 General overview of Sierra Leone

1.1 Country Information

The Republic of Sierra Leone (Fig.1.1) is located on the West Coast of Africa, between latitudes 7 and 10 north and longitudes 10.5 and 13 west. It is bordered by Guinea to the north and east, Liberia to the southeast, and the Atlantic Ocean to the west and southwest [1,2,3,4]. Sierra Leone covers a land area of 71,621 km^2 and a total area of 71,740 km^2. It has a population of 5.4 million (est. 2011, [3]). The capital and biggest city is *Freetown* (approx. 1.1 million, 2003 [4]), other important cities are *Bo* (174,354), *Kenema* (143,137), *Makeni* (87,679) and *Koidu-Sefadu* (87,539) [5]. The Republic of Sierra Leone is composed of four regions, the Northern Province, Southern Province, the Eastern Province and the Western Area. The first three provinces are further divided into 12 districts – *Kambia*, *Port Loko*, *Bombali*, *Koinadugu*, *Kono*, *Tonkolili*, *Moyamba*, *Bo*, *Kenema*, *Kailahun*, *Pujehun*, and *Bonthe*. The districts are further divided into 149 chiefdoms. The Western Area is divided into the Western Area Urban and the Western Area Rural (Fig. 1.2) [6].
Several ethnic groups make up Sierra Leone, including the *Temne* (30 %), the *Mende* (30 %) and others (30 %); *Creole* (*Krio*) 10 %; refugees from Liberia's recent civil war, small numbers of Europeans, Lebanese, Pakistanis, and Indians [2, 4]. Languages: English (official), *Mende* (southern vernacular), *Temne* (northern vernacular), *Krio* (lingua franca). Religions: Islam 60 %, Indigenous 30 %, Christian 10 % [4].

1.2 Recent History

Since gaining independence from Britain in 1961, Sierra Leone has had a chequered history. Periods of democratic government have been punctuated by military coups - the first in 1967 and the most recent in 1997. The country experienced a brutal rebellion that started in 1991 and ended in 2002, following British and UN intervention. The rebellion caused great damage to the country's human, infrastructural and economic resources.
Prior to the civil war, Sierra Leone had established an active mining sector built upon significant exports of diamonds, rutile and bauxite. Although relatively modest by global standards, the sector was significant in terms of the country's population and GDP. Mining and quarrying provided a livelihood for over 250,000 people, and employed about 14 % of the total direct and indirect labour 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. Sierra Leone slipped off the investment radar for most major mining companies well before the outbreak of hostilities in 1991.

Fig. 1.1: Relief map of Sierra Leone [3].

The effective nationalization of the diamond industry and increasing political instability relegated the country to, at best, a speculative exploration target. Although the established rutile and bauxite operations continued to play an important economic role, large-scale exploration activities effectively came to a stand-still more than 20 years ago. As the sector's economic importance declined, so too did the capacity of key Government departments to regulate sector developments.

Fig. 1.2: The Districts of Sierra Leone.

The end of hostilities marked the start of a strong economic recovery. Double-digit economic growth during 2001 and 2002 led to a significant period of economic expansion. Real GDP growth averaged nearly 8 % per annum for the period 2003 to 2006 and is forecast by the International Monetary Fund to continue at over 6 % per annum in the medium-term. The mining sector has played an instrumental role in Sierra Leone's nascent economic recovery. The rate of growth recorded in the mining sector has exceeded that in the remainder of the economy. The resurgence of the mining sector has been two-fold. First, the Government – with external support – has had considerable success in increasing the proportion of diamonds mined that pass through official channels. Official exports have increased to 582,000 carats in 2006, with 84 % of this amount being mined by artisanal and small-scale miners. The U.S. dollar value per carat has also increased significantly, suggesting that larger, more valuable diamonds are increasingly returning to official export channels. Second, three mechanized mines have been reactivated. The country's first kimberlite diamond mine has been operating since 2004 and is progressively expanding production. Also, both of the rutile and bauxite deposits that were developed before the war are once again being mined. The resumption of rutile and bauxite mining has re-established the two mines as two of the largest private sector employers in Sierra Leone. Prior to their closure these mines employed over 3,000 workers. The vast majority of income-earning opportunities generated by the mining sector, however, are in artisanal diamond mining. The World Bank has estimated that up to 40,000 people are directly engaged in mining for diamonds and that the associated population of immediate family dependents could include 100,000 to 200,000 people. If those people that are indirectly dependent on artisanal diamond mining through forward and backward linkages are included, the World Bank estimate reaches 200,000 to 400,000 people dependent upon artisanal mining for the greater part of their livelihood. This represents between 4 percent and 8 percent of the population [4].

1.3 Geography and Climate

Sierra Leone's 400 km coastline overlooks the North Atlantic Ocean. The country can broadly be divided into three areas: mangrove swamps and beaches along the approximate 110 km coastal belt of low-lying land; a belt of low-lying wooded land in the immediate interior; and a mountain plateau near the eastern frontier rising 1,200- 2,000 m with a rich timber forest region. The Western Area encompasses the Sierra Leone Peninsula, on which the capital and main commercial centre of *Freetown* stands; is 15 km long and 6 km wide. A mountainous promontory, it rises in places to 100 m above sea level, is one of the few parts of the West African Coast where there is high land so near to the sea.

The climate is tropical, with two seasons determining the agricultural cycle: the rainy season from May to November, and a dry season from December to May, when dry winds blow in off the Sahara Desert and the night-time temperature can be as low as 16 °C. The average temperature is 26 °C and varies from around 26 °C to 36 °C during the year [1,2,3,4].

1.4 Hydrography

The country is drained by nine major rivers. These are the *Rokel/Seli*, *Pampana/Jong*, *Sewa, Waanje*, and the coastal streams and creeks, which originate inside the country. The rest are the *Great* and the *Little Scarcies* and the *Moa River*, which originate from the *Fouta Jallon Plateau* in the Republic of Guinea, and the Mano River which originates from the *Republic of Liberia*. These rivers range in length from 160 km for the *Great Scarcies* to 430 km for the *Sewa River*. They drain areas from 2,530 km^2 for the coastal streams and creeks to 14,140 km^2 for the *Sewa River*.

The *Sewa River* is the most important commercial stream in Sierra Leone, West Africa. Formed by the junction of the *Bagbe* and *Bafi rivers*, which rise in the north-eastern part of the country near the Guinea border, it flows 240 km in a south-south-westerly. The *Sewa* joins the *Waanje River* 48 km east-southeast of *Bonthe* to form the *Kittam*, a distributary that empties into the Atlantic via the *Sherbro Strait*. The *Sewa*'s upper reaches are extensively panned for diamonds; its basin from *Sumbuya* northward through the area around *Yengema*, leased to the Sierra Leone Selection Trust, is also worked for diamonds. South of *Sumbuy*a, which is the head of navigation (68 km upstream from the confluence with the *Waanje*), piassava (exported for the manufacture of brooms and brushes) and swamp-rice cultivation are important commercial activities [13].

2 Geologic Overview

The high rainfall, hot climate, dense vegetation, widespread thick residual laterite, and lateritic detritus as well as poor internal communications have made Sierra Leone a difficult country in which to carry out geological and mineral investigations.

Sierra Leone occupies the central portion of an Archean craton that was disrupted by the opening of the Atlantic Ocean. The eastern cratonic fragment extends from the Western Sahara and Anti-Atlas Mountains eastward to the Hoggar and southward to Mauritania, Senegal, Guinea, Sierra Leone, Liberia, Ivory Coast, and Ghana. The western portion of the craton is now to be found forming the Guyana Shield extending from Venezuela to French Guiana and Brazil [8]. The geology is divisible into two major tectonostratigraphic units. The eastern one is part of the stable Precambrian West African Craton and consists of high- grade metamorphic rocks and granitic gneisses. The western unit contains elements of an orogenic belt named the '*Rokelides*' or '*Rokel River Group*' that was deformed during the Pan- African tectonothermal event, about 550 Ma ago. A minor, 20–40 km wide costal strip is made up of Pleistocene to Recent marine sediments (Fig. 2.1) [7].

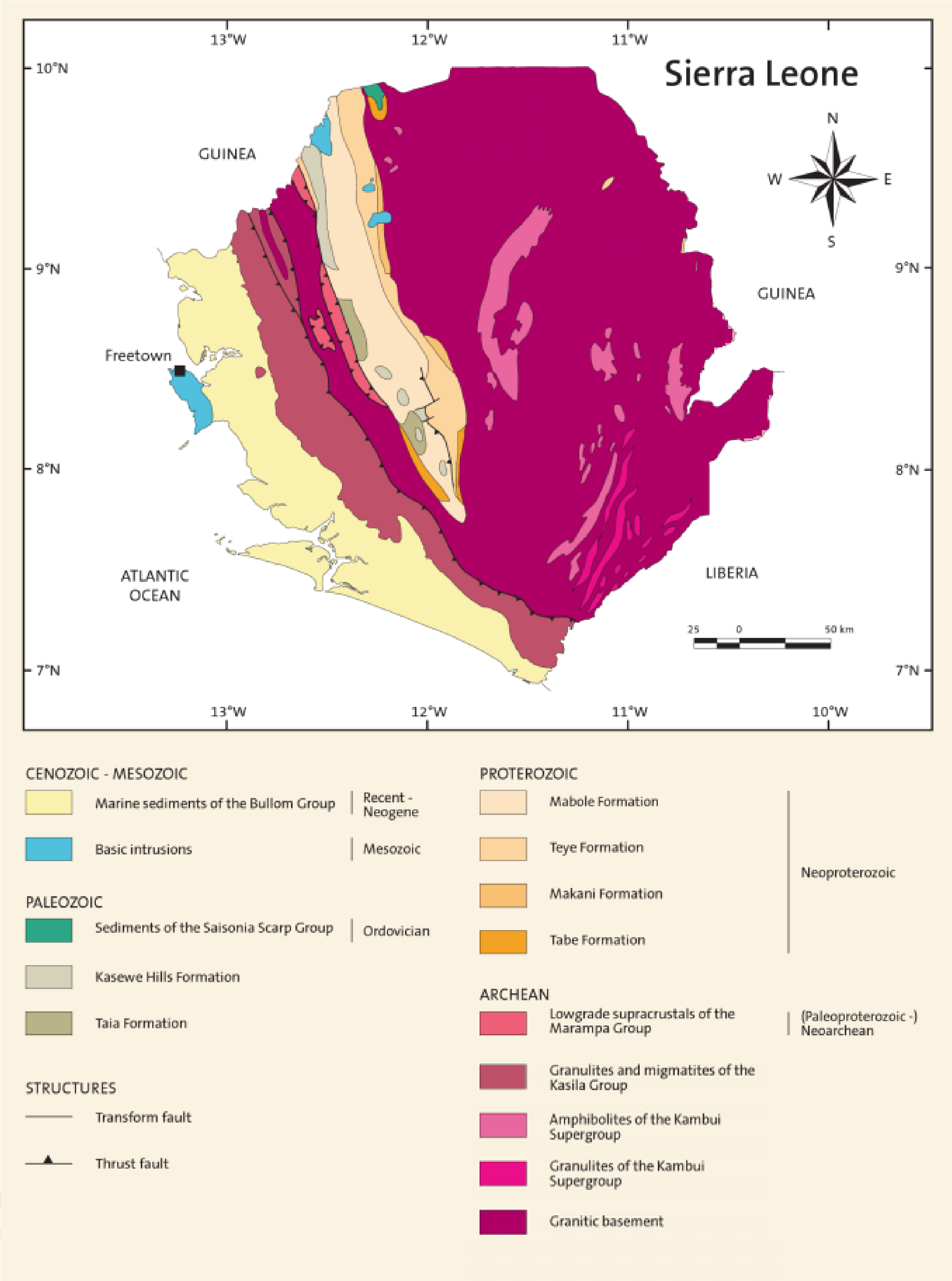

Fig. 2.1: The geology of Sierra Leone (simplified after [7] and [14]).

2.1 Archean Rocks

2.1.1 Granitic Basement

The greater part of Sierra Leone is occupied by an ancient granitic shield containing gneissic relics of still older formations. They date from the early Archean and include coarsely crystalline granites, quartz granulites, and hematitic granulites.

Upon them, apparently unconformably, lie serpentines, amphibolites, conglomerates, and iron-stones of the ophiolitic *Kambui Group* which forms the *Sula Mountains* and the *Kangari*, *Kambui*, *Nimini*, and *Gori* ranges of hills. As these have also been deformed and metamorphosed together with the underlying gneisses and intruded by late and post- orogenic granites it seems clear that there have been several epochs of granite formation.

In northern Sierra Leone a complex history of granite formation, migmatization, deformation along east-west axes, and pegmatite formation can be found. This thermotectonic episode is defined as the I,eonean and it is assumed that it preceded the deposition of the *Kambui Group* [8, 9].

2.1.2 Kambui Group

The supracrustal rocks of this group can be divided into two units on the basis of their size, stratigraphic thickness, lithologies, metamorphic grade, and distribution [10]. The western group includes the larger greenstone belts of the *Sula Mountains*, *Kangari*, south *Nimini*, and the *Gori* hills greenstone belts, which are up to 130 km long with thick succession (up to 6.5 km) metamorphosed to amphibolite grade. Banded iron-formation is a relatively minor lithology, although this unit includes the *Marampa* and *Tonkolili* iron ore fields. In south eastern Sierra Leone, Liberia and western Ivory Coast there are small schist relics (maximum 40 km long) with thinner stratigraphic succession (rarely greater than 1 km) in which banded iron-formation is dominant and gabbro-anorthosite complexes are minor. Rollinson [10] states that geochronological evidence suggests that the two groups of supracrustal rocks are contemporaneous and that they represent a primary zonation of the Archean in southern West Africa.

The ophiolitic *Kambui* schist group is subdivided into three groups; a lower ultramafic, a middle mafic, and an upper sedimentary group. The ultramafic group includes tremolite-chlorite-schists, talc-chlorite-schists, and anthophyllite-schists and serpen-finite interbedded with amphibolite and more rarely with metasediments. The mafic group is made up entirely of amphibolites which vary in size, are pillowed, and have vesicular and amygdaloidal structures, indicating that the original basaltic pile was composed of pillowed and massive lavas and intrusive sills with chilled margins. Amphibolites from the *Kambui* belt are olivinetholeiitic in composition. In the sedimentary group he commonest rocks are greywacke, turbidite, and quartzite with minor amounts of fuchsite-quartzite, conglomerate, metachert, and banded iron-formation. The conglomerates contain pebbles of local derivation, but clasts of low potash granites indicate that continental crust was nearby during their deposition. The metamorphic grade is middle amphibolite facies. The eastern group of supracrustals in southeast Sierra Leone have less regular stratigraphies and more dominant sedimentary units with smaller mafic and ultramafic units. Banded iron-formation is very common as are quartzite, greywacke, and pelitic schist. Metamorphic grade varies from greenschist to granulite facies, commonly with sillimanite or kyanite [8, 9].

2.1.3 Kasila Group

A distinctive group of mafic gneisses and granulites lies along the south-western part of the West African craton in Sierra Leone and passes south-eastward into Liberia. They consist of gabbros, amphibolites, hornblende schists, garnet-mica schists, and charnockitic and anorthositic granulites with a predominantly north-west to southeastern strike and showing some signs of isoclinal folding and intensive shearing. The lithology of the *Kasila* Group is dominated by fine- to medium-grained basic granulites with minor horizons of quartz magnetite, quartz diopside, and sillimanitic rocks. The granulites are intruded by deformed gabbros, anorthosites, and ultramafics in which relict igneous textures have survived the Pan-African reworking in zones where shearing was less intense [8].

2.1.4 Marampa Group

Lying to the west of the Proterozoic Rokel River Group sediments (Fig. 2.1) there is a group of biotite-muscovite-schists, garnet-biotite-schists, and feldspathic and hematitic schists forming outcrops along a 60 km zone. In the westernmost outcrops greenish chlorite-schists and muscovite-schists predominate. Inliers of granite are exposed, but their relationship with the *Marampa* schists is not clear due to poor exposures. At the *Ghafal* and *Masaboin* hills the *Marampa* schists have been affected by tight folding along northeast axes and by open folding along northwest axes. The *Marampa* Group is included in the Archean supracrustal formations, but their thin successions are dominated by banded iron-formation [9]. Thus, they may be of a different age from the other belts. Their lower metamorphic grade may simply reflect their tectonic situation, however, and the presumption must be that they represent Archean supracrustals affected by the Eburnean metamorphism or that the Pan-African episode has reset their isotope ratios giving them an Eburnean age [8, 9].

2.2 Proterozoic and Paleozoic Rocks

2.2.1 Rokel River Group

The Proterozoic to Paleozoic *Rokel River Group* extends southward from Guinea into Sierra Leone where it occupies a belt c. 30 km wide, trending SSE for some 225 km into southern Sierra Leone (Fig. 2.1). The *Rokel River Group* was folded and slightly metamorphosed by the *Rokelide Event* c. 500 Ma ago, the time of the Pan-African thermotectonic event. The group can be divided into six formations; the *Tabe, Makani, Teye, Mabole, Taia* and *Kasewe Hills* Formations [11].

2.2.1.1 Tabe Formation

The Tabe Formation rests unconformably on Archaean granitic basement and outcrops along the eastern margin of the main *Rokel River Group* outcrop, but is confined to the southern end of the western margin. Outliers of the *Tabe Formation* occur in northern Sierra Leone, both to the E and W of this main outcrop. The *Tabe Formation* has been subdivided into 3 members, the *Tibai*, *Taban* and *Dodo* Members, the first 2 being glacigenic [12].

The *Tibai* Member consists of 3 main lithologies. Poorly sorted conglomerates, originally interpreted as a marine trangressive deposit, have been shown to be tillites [12]. Closely associated with the tillites are laminated siltstones and fine sandstones with isolated granitic lasts which have been interpreted as possibly lacustrine rhythmites containing ice-rafted dropstones. Interbedded with the rhythmites are lenticular graded feldspathic sandstones which are considered to be channel turbidites.

The *Taban* Member (formerly the *Taban* Formation) is composed of feldspathic sandstones and was considered to be post-*Rokelide* orogenic molasse. However, since the *Taban* Member exhibits greenschist metamorphism and folding consistent with other pre-orogenic *Rokel* River Group strata, it can be considered that these deposits are pre-orogenic. Closely associated with these rocks are feldspathic sandstones of the *Dodo* member, which overlie the *Tibai* Member but may be laterally equivalent in places [11].

2.2.1.2 Makani Formation

The *Makani* Formation is composed of grey silty clays with interbedded orthoquartzite and subarkose beds. These deposits are interpreted as well-worked, possibly neritic zone sediments [11].

2.2.1.3 Teye Formation

The overlying *Teye* Formation is a thick, structurally complex sequence of purplish-brown to grey shales, interbedded with beds of greenish-grey sandstones from 5 mm to 0.5 m thick.

Grading, sole structures, cross-lamination and mud clasts are all present in sandstones intercalated with shaly layers. However, some sequences consist almost entirely of siltstone and shale and may be distal turbidites, but they can as readily be interpreted as quiet water outer shelf sediments. The intermittent exposure and complex structure preclude any attempts at elucidating palaeocurrent directions [11].

2.2.1.4 Mabole Formation

The *Mabole* Formation is composed dominantly of shales with interbedded siltstones, orthoquartzites, subarkoses and arkoses. Ripplemarks, crossbedding, detrital specular haematite and wellrounded orthoquartzites let suggest that the *Mabole* Formation sediments were deposited in shallow water, probably in a deltaic environment [11].

2.2.1.5 Taia Formation

The *Taia* Formation consists of grey mudstones and shales with a few interbedded silty and sandy layers. These deposits are interpreted as pro-delta sediments situated off the *Mabole* Formation deltas [11].

2.2.1.6 Kasewe Hills Formation

The *Kasewe Hills* Formation, which occurs in lenses up to 2 km thick within the *Mabole* and *Taia* Formations, is composed of volcanic tuffs and lavas of varying. Andesites are dominant, but spilites, basalts and tuffs of dacitic composition also occur. Pillowed spilites show that some eruptions were sub-aqueous, while air-borne pyroclastics are also present, both interbedded with lavas, and further from the volcanic centres, interbedded with Taia Formation pro-delta deposits [11].

2.2.2 Saionia Scarp Group

The Paleozoic Saionia Scarp Group covers an area of 50 km^2 in northern Sierra Leone (Fig. 2.1), and extends northwards into Guinea. The Saionia Scarp Group rests unconformably on Archaean granitic rocks and on Rokel River Group conglomerates, the latter folded during the Pan-African thermo-tectonic event. The Saionia Scarp Group sedimentary sequence is 190 m thick and is intruded by several dolerite sills, up to 90 m thick, of probable Triassic age. The Group has been subdivided into the Moria and Waterfall Formations. The lower Moria Formation consists mainly of sandstones, with a basal conglomerate in places. The lower sandstones are feldspathic with well-developed heavy mineral laminae occurring in truncated sets. The overlying sediments are well-sorted quartz arenites exhibiting planar cross-bedding which in turn are overlain by red and purple laminated shales containing some quartz silt. The sandstones of the Moria Formation are considered to have been deposited under littoral and shallow shelf conditions, while the overlying shales were perhaps deposited in a quieter water shelf environment. The overlying *Waterfall* Formation consists of 150 m of laminated argillites with lenticular coarsegrained sandstone beds. The laminated mudstones display alternation of coarse and fine laminae. They contain randomly dispersed angular to subrounded clasts up to 0.3 m in diameter, consisting of sedimentary, metasedimentary and granitic rocks. The laminations are depressed and broken beneath the clasts [11].

2.3 Cenozoic – Mesozoic Rocks

2.3.1 Freetown Complex

The *Freetown* peninsula and the *Banana Islands* are part of an apparently funnel-shaped body of gabbroic rocks of which the greater part lies out to sea. The complex consists of a 6 km thick series of cumulate rocks of gabbroic composition, containing layers of dunite, troctolite, olivine-gabbro, gabbro, leucogabbro and anorthosite [8, 11]. The complex is intruded into the gneisses of the *Kasila* Group and overlain by sediments of the *Bullom* Group whose lower beds are of Eocene age. Sedimentation structures such as cross-bedding are common in the gabbro layers and some 6,000 m of thickness is exposed [8]. The complex has been reliably dated as 193 Ma. The outcrop limits of the complex define an arc. Layering dips radially inwards from this arc, and a hypothetical 'centre' is deduced to lie 16 km WSW of *York*. The layering may be divided into 4 major zones on the basis of large-scale variations in mineralogy and topographic expression. Each zone can be seen as the result of a single magmatic event. The base of each zone is olivine-rich, and the top anorthositic. Within the zones are many rhythmic units on a hectometre scale, and within each rhythm is a centimetre-to-metre-scale banding. Both zones and rhythms tend to be more olivine-rich at their bases and plagioclase-rich at their tops, so in effect rhythms are small-scale duplications of zones. Rhythmic layering and banding is more developed in the basal portions of zones and rhythms, while massive, lenticular anorthositic rocks, which are locally transgressive into overlying rocks, characterize the tops of zones. Mineralogically, the *Freetown* Complex displays few of the characters expected in large layered intrusions. The minimal cryptic layering present is unrelated to height above the base of a zone or rhythm. Order of cumulus crystallization is ilmeno-magnetite as immiscible droplets, olivine, pyroxene, plagioclase; this gives rise to the following stratigraphy of rhythms and zones:

Top: Anorthosite → Leucogabbro → Gabbro → Olivine gabbro → Troctolite

Bottom: Ilmenomagnetite-rich troctolite.

Sulphides are ubiquitous but occur in small amounts, either as crystallized droplets of immiscible liquid trapped as inclusions in olivine and plagioclase, or as late-stage hydrothermal veins and replacements. Copper, nickel, platinum and gold have been recorded in association with sulphides [11].

2.3.2 Dolerite dykes and sills

Dolerite dykes and sills are widespread in Sierra Leone. Dolerites are most common close to the coast, intruding Precambrian rocks and those of the *Rokel River* Group as coas-parallel dyke swarms traceable into Liberia (Fig. 3.2). Further inland, the dykes become thinner and occur with more variety of trends, paralleling major NE, ESE faults. The dykes show a variation in mineralogy, but there is a consensus of opinion that they are consanguinous. Some contain olivine and orthopyroxene, while others show only relicts of these minerals. All dykes consist mainly of a zoned labradoritic plagioclase and brownish synneusis clots of augite occurring as subophitic intergrowths. Porphyritic dykes, containing abundant 3 cm laths of plagioclase with marginal subparallel alignment of crystals, also occur. Magnetite, ilmenite, and graphic quartz-feldspar intergrowth are common accessory phases [11]. Dolerite sills form resistant caps of 2 major mountains in Sierra Leone, *Bintumani* (1,948 m) and *Saionia Scarp* (1,000 m). Sills occur at progressively lower levels when traced westwards, forming similar tabular structures up to 120 m thick in the *Rokel River* Group at a height of 150 m [8, 11]. The progressive decrease in sill elevation with respect to sea level towards the coast may be evidence for a post-Triassic continental margin subsidence associated with the opening of the Atlantic Ocean and the formation of new continental. The small sills on *Bintumani* are banded on a metre scale, suggesting cumulate formation. The 3 separate sills on *Saionia Scarp* make up a total intrusion thickness of 200 m, and these indicate a large scale mineralogical variation due to crystal settling. The sills have mineralogical composition similar to that of the dykes, and are presumed to be structurally and temporally related.

2.3.3 Bullom Group sediments

Bullom Group sediments occupy the low-lying coastal plain of Sierra Leone (Fig. 2.1). These deposits extend up to 50 km inland and are found at heights of up to 40 m above present sea level. Outcrops are rare and generally poor with the exception of 25 m high sea-cliffs at *Bullom*, N of *Freetown* [8, 11]. The *Bullom Group* consists of a laterally variable sequence of poorly consolidated, near horizontal, often iron-stained gravels, sands and clays with occasional intraformational laterites and lenticular seams of lignite. The clays are generally kaolinitic, red, purple and white in colour and in the *Bullom* cliffs contain plant remains. In a borehole drilled to a depth of c. 120 m (100 m below present sea level), E of the *Freetown* Peninsula, a sparse fish and mollusc fauna obtained from borehole sludges indicated an age not older than Eocene and possibly as young as Miocene for near basal sediments. The sands, sometimes graded, but rarely cross-bedded, are generally poorly sorted, with a clay matrix; partially disintegrated feldspars occur. Quartz grains are very angular and under the scanning electron microscope show no evidence of marine or prolonged fluvial activity. Interbedded with the sands are occasional grit beds, stringers of rounded quartz pebbles, and horizons of kaolin clay clasts. Intraformational laterites occur within the sands and often form puddingstone horizons. Rare, thinly bedded calcareous clays and grits have also been recorded [11].

3 Mineral Commodities

Sierra Leone's primary mineral resources are diamonds, rutile, bauxite, gold and iron ore. The mineral sector in Sierra Leone is made up of three sub-sectors:
a) Large-scale production of non-precious minerals – rutile and bauxite;
b) Large scale production of precious minerals – diamonds;
c) Artisanal and small-scale production of precious minerals – mainly diamonds, and to a much lesser extent, gold [4].
The mining sector was a significant contributor to Sierra Leone's economy; it accounted for about 90 % of export revenues, mainly from diamond exports, and 20 % of the gross domestic product (GDP). Sierra Leone was the world's 10th ranked producer of diamond by volume in 2009 and the world's third ranked producer of rutile [15].
For a list of deposits and exploration targets have a look at Tab. 6.1 and the referring figures Fig. 6.1 to Fig. 6.3.

3.1 Diamonds

The Sierra Leone diamond fields cover an area of about 20,000 km^2 (about one quarter of the country) in the south-eastern and eastern parts of Sierra Leone (Fig. 3.1). The actual diamond producing areas are concentrated in the *Kono*, *Kenema* and *Bo* Districts and are mainly situated in the drainage areas of the *Sewa*, *Bafi*, *Woa*, *Mano* and *Moa Rivers* [4].
Alluvial diamonds were first found in Sierra Leone in 1930 in an area which later became the *Yengema* lease of the Sierra Leone Selection Trust (SLST). This company was formed in 1934 to develop and mine the diamonds in the streambeds and terraces of fight bank tributaries of the *Bail River*, a major tributary of the *Sewa River*. Diamonds occur along the

course of the *Sewa* below its confluence with the *Bail* and often spectacular high grade recoveries were made by local people in potholes.

Kimberlites, the primary host rocks for diamonds, have been by SLST in 1948 near *Koidu* and subsequently two small pipes and numerous dykes, located in about 30 parallel dyke zones, were found in the *Yengema* area. Two similar kimberlite dykes were found by SLST in 1952 in the *Tongo* area, 50 km to the south of *Yengema*. The Sierra Leone Geological Survey, following up the trace of workings by local miners, found similar dykes at *Panguma*, west of *Tongo*, in 1960 [16].

Sierra Leone is known for producing mostly gem quality diamonds including some spectacularly large stones of very high value. The largest ever discovered (February 1972) was a 969.8 carat diamond code-named the “Star of Sierra Leone” (the third largest diamond ever found worldwide) [4].

Fig. 3.1The diamond fields of Sierra Leone [19].

Kimberlite occurs mainly as dykes, but also small pipes and a dyke-enlargement ring complex structure are also recorded. In depth they are all related to dykes following deep-seated fractures in the granitic shield [11]. They occupy two fault-bounded basins in the east of the country, developed across migmatized gneiss, and granodiorite, intruded by late kinematic granites and enclosed by hill ranges of amphibolitic supracrustal rocks [17]. Two main areas contain kimberlite, the *Yengema-Koidu* and the *Tongo* Leases, 50 km apart (Fig. 3.1).

The regional structural control of kimberlite magmatism in Sierra Leone and West Africa as a whole is based on the association of possible major ocean fracture zone continuations in continents with fundamental Archaean lineaments (Fig. 3.2).

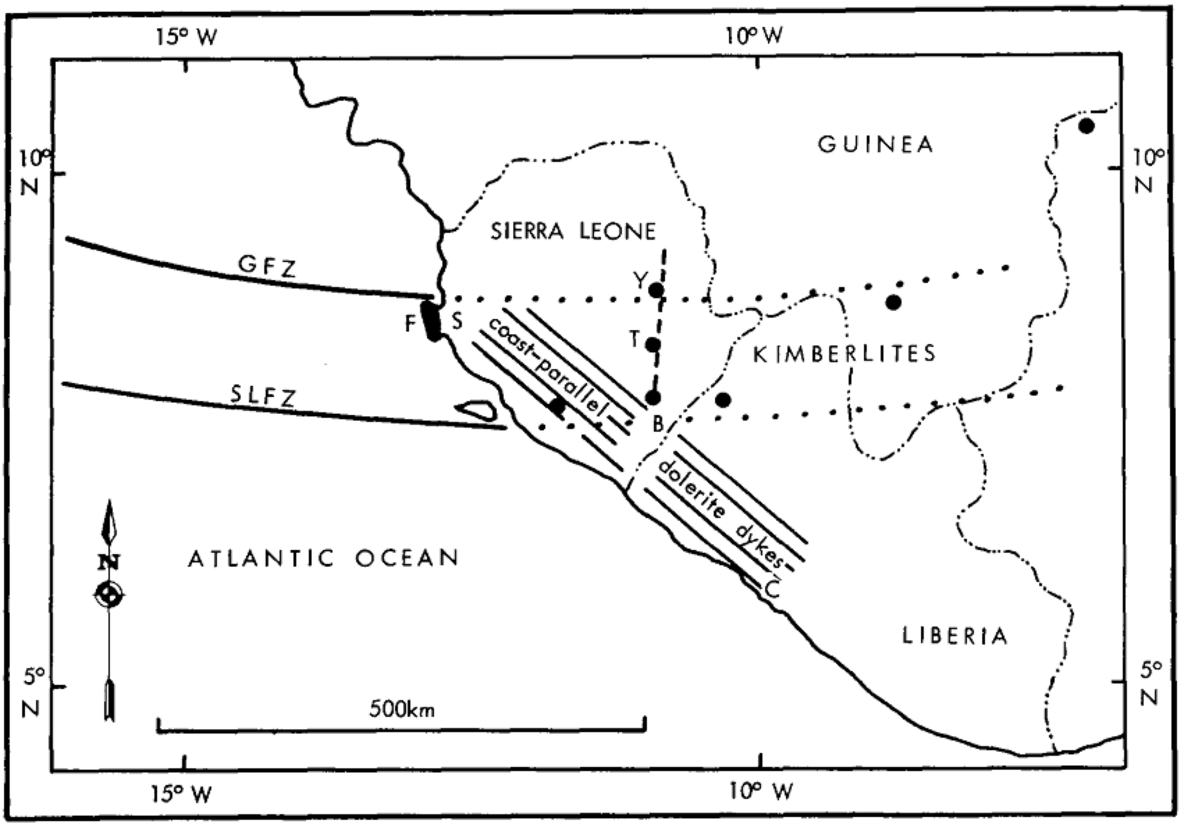

Fig. 3.2: Relationship between magmatism and regional structure in Sierra Leone and adjacent countries. B, Bagbe; C, Cape Mount; F, Freetown Complex; S, Songo; T, Tongo; Y, Yengema; GFZ, Guinea Fracture Zone; SLFZ, Sierra Leone Fracture Zone; solid circles, kimberlite; dotted lines, hypothetical continental continuations of fracture zones; dashed line, major fault controlling kimberlite magmatism [11].

The dyke zones are bordered to the E and W by 2 N-S trending regional fault zones, and within these faults the dykes generally trend WSW-ENE (striking consistently at 70° to 74° from true north), cutting other Archaean faults and Permo-Triassic dolerites. The dyke dips are steep to vertical.

The kimberlites intruded into the Archaean basement during the Cretaceous (96 Ma by $^{87}Sr/^{86}Sr$ method), and the presence of feldspathic sandstones, shales and basaltic rocks in the kimberlite breccias indicates erosion of pre-Cretaceous rocks not represented at the present erosion level. Estimates of this erosion are upwards of the order of 300 m, based on the quantities of diamonds released into the drainage system. The coincidence of kimberlite intrusions with sea-floor spreading structures suggests that the timing of kimberlite magmatism is coincident with change in plate movement [8, 11, 17, 18].

The ***Yengema-Koidu Area*** (8°38'N; 10°59'W) consists of three Mesozoic kimberlite pipes, a ring-dike structure, and multiple sets of 4 en-echelon kimberlite dykes zones (Dyke Zone A, B, C, and D)[20]. A small blow on Dyke Zone A, and another blow on Dyke Zone B were discovered by Koidu Holdings in 2005 [21]. The dykes occur as vertical, curvilinear arrays, with individual dykes between 50 mm and 1 m wide and up to 300 m long and altogether make up a total strike length of 192 km. The dykes, some dilational and others replacive, contain abundant xenoliths of the granitic host rock. Progressive enlargement of dykes at intersections with faults ultimately leads to pipe formation. The kimberlite dykes strike N55°E and are both older and younger than the kimberlite pipes. Three small pipes have been discovered with surface areas of 2,000 m^2 (Pipe 1), 4,500 m^2 (Pipe2), and 2,500 m^2 (Pipe 3). The dykes and a dyke-enlargement complex in the *Yengema* Lease are surrounded by 3 m aureoles of fenite and calcite, talc and analcite mineralization. Breccias within the pipes contain a variety of mantle and crustal xenoliths [8, 11].

Pipe 1 at *Koidu* is characterized by typical brecciated blue-green kimberlite where two facies have been recognized; a phlogopite rich and serpentine rich kimberlite. Crustal xenoliths are abundant in both types.

At Pipe 2 three distinct kimberlite facies are recognized. A dominant tuffaceous fine grained kimberlite with approximately 50 modal percent of small angular crustal xenoliths, is the dominant type. The second type is a carbonatitic kimberlite with approximately 50 wt.% CaO, and 20 wt.% SiO_2, and the third type is kimberlite similar to Pipe 1 with minor crustal xenoliths.

Pipe 3 is situated to the northwest of Pipes 1 and 2 along the Dyke Zone D, but little else is scientifically known because it lies under a swamp.

The dykes are distinctive and differ from the pipes by being free of crustal xenoliths, significantly finer grained, and mafic in colour. Five major classes are recognized based on the alteration of olivine to serpentine, serpentine + calcite, calcite, or by being partially altered or completely unaltered [22].

In the ***Tongo Area*** (8°12'N; 11°4'W) only dykes are found which can be divided into four zones. The dykes are of similar composition, structural setting and age as those in the *Yengema-Kuido* Lease. The kimberlite rock is usually a porphyritic to fine-grained grey to green material composed predominantly of serpentine, phlogopite, olivine, pyroxene and carbonate. Pyrope and picro-ilmenite megacrysts are common and are used as indicator minerals during prospecting. The rock is cut by numerous veins of calcite and serpentine, the former often fenitizing the adjacent wall-rocks. The magma shows signs of chilling against the upper crustal xenoliths, which are frequently very well rounded. The penetration of the magma into the granitic host rocks on an intimate scale suggests that it was of a very low viscosity. The kimberlite dykes tend to form branching stringer adjacent to the main dike, as for example in the *Lando* zone in *Tongo* which is up to 12 m wide but only contains about 3 m of kimberlite [8]. Hall [25] also mentions the *Panguma* kimberlites southwest of *Tongo* as a kimberlite group of its own, which nowadays are included into the *Tongo* Lease.

Alluvial Deposits

Hall [25] divides the *Yengema-Koidu* field into seven areas of alluvial diamonds: *Koidu* area, *Yengema* area, *Lower Moinde*, *Yomadu-Shongbo*, *Gbobora*, *Tefea* area, and *Upper Sewa*.

The *Sewa* fields along the *Sewa River* they divide into 15 areas: *Nimiyema*, *Jagbwema*, *Barma*, *Boajibu*, *Kobundala*, *Baoma Oil Mill*, *Leveuma*, *Yamandu*, *Jomu*, *Sembehun*, *Wubunge*, *Petewoma*, *Hima*, *Sumbuya*, and *Bagbo*.

Alluvial deposits around the *Tongo* kimberlites get divided into three areas: the *Tongo* drainage, *Woa* and tributaries, and *Luya*.

13 other areas are listed in their report in the *Kenema District*: *Bundoye*, *Panguma*, *Foindu*, *Beeya*, *Kenja*, *Lower Woa*, *Male*, *Putehun*, *Segbwema*, *Middle Moa*, *Zimmi*, *Moro*, and *Malema*.

Minor occurrences are *Teye*(*Mongeri*), *Koye* (*Selu*), *Kendi* (*Gau*), *Tabe*, *Lower Waanje*, *Masau*, *Mongo*, and *Kankana*.

Since their extrusion, the diamondiferous kimberlites and the surrounding country rocks have probably been eroded by at least 1,000 m. During this erosion, diamonds in excess of 50 Mcar have been released from the two kimberlite outcrop areas at *Koidu* and *Tongo* and become widely dispersed down the *Bari-Sewa* and *Moa River* systems and their antecedents throughout most of the Cainozoic [17].

Consequently the diamonds have been repeatedly sorted, deposited released by renewed erosion of alluvial deposits during succeeding erosion cycles, and then re-deposited. These mechanical processes have concentrated the diamonds in the gravels and improved their quality. Diamonds have travelled at least 100 km in the river systems from their sources. The processes of concentration have also affected other resistant minerals, particularly corundum, zircon, limonite, rutile, chromite, and tourmaline, which have become trapped in depressions in the beds of streams, in joints, behind rock bars, and in crevices. In most cases the diamondiferous gravels lie next to the bedrock and may be covered by 20 m of gravels, silt, and clay [8].

The present Atlantic-directed drainage has probably been evolving since the initiation of Atlantic rifting in this area about 185 Ma ago and must have been a well-developed river system by the time of kimberlite intrusion. The regional tectonic situation is that of a slowly subsiding continental margin allied to a steadily uplifting watershed area, and this has produced an incising river network on the resulting regional slope. This incision, perhaps accelerated by Quaternary climatic and sea-level fluctuations, has given rise to an apparently superimposed drainage network cutting across the major rock formations and shows close correspondence with more minor structural features at a local level. River capture has been relatively frequent in such circumstances, as the incising river network has adjusted to the variations in the underlying structural framework, and this has resulted in a rather wide distribution of diamond deposits in some areas away from the trunk streams, the *Sewa* and the *Moa*.

During transport diamonds are sorted by size such that the farther from the source, the smaller the average size of the diamonds. A diamond population is not just composed of diamonds of differing sizes but also of varying colours, crystal forms, and diamond types. Diamond populations from different sources thus are composed of varying percentages of bort, octahedra, dodecahedra, cleavage stones, translucent or coated diamonds, etc. A relation of the percentages of clear, coated, and bort diamonds at certain localities along the *River Sewa*, including the area around the kimberlites at *Yengema* is given in the following table:

Tab. 3.1: Relation of the percentage of clear, coated, and bort diamonds at certain localities along the River Sewa (Sutherland [26]).

Locality	Clear (wt. %)	Coated (wt. %)	Bort (wt. %)
Yengema	50	45	5
Upper Sewa	58	38	4
Middle Sewa	66	30	4
Lower Sewa	77	20	3

Quite clearly there is a preferential loss of bort and coated stones during transport. It seems probable that the bort is lost by breakage into tiny particles. The consistent reduction in the proportion of coated diamonds down the *Sewa* may be due to the effects of surface attrition, since the green coatings on the Sierra Leone diamonds are frequently rather shallow and are particularly brittle [26].

Another, less known alluvial diamond fields can be found in the *Kamakwie* area in the north of Sierra Leone. The Northern Province has been known traditionally for large deposits of iron ore in *Port Loko* District and gold in *Tonkolili* and *Koinadugu* Districts. The existence of diamonds in the North was first noted in the mid-1980s when it was rumoured that a resident of *Kabatha* village had found a diamond. Theories about the existence of diamond deposits in the Northern region have been based on trial and error, due to a lack of scientific research.

The Geological Survey has now conducted short intensive reconnaissance surveys of the areas in question- the *Kamaranka-Kamakwei* and the *Kambia* zones. The former is underlain by basement granite and gneiss, and the latter by the *Kasila* gneisses, and basement granite. Mineralogical Studies of heavy mineral samples have clearly indicated the presence of kimberlite indicator minerals, picro-ilmenite and pyrope garnets, g6 and g7 garnets. The latter two have been used in South America to uncover kimberlite dykes and pipes and this supports the original suspicion that the provenance of these diamonds have been formed from small numerous and thin kimberlite dykes which have been weathered to a lesser or greater extent. These diamonds are associated with gold, which has quite recently been recovered as a primary and secondary product.

The first official mining license was issued in the North in 2002, thus, legitimizing diamond mining in the region for the first time. Nevertheless, there are indicators that small kimberlite dykes exist in the Northern Province. In 2005, the Acting Deputy Director of the Geological Survey in the Ministry of Mineral Resources told that the kimberlitic structure in the North points to neighbouring Guinea [4]. The Sierra Leone Diamond Company (now knows as African Minerals) was carrying out prospecting work around *Kamakwie* to assess the viability of these kimberlite dykes. Meanwhile, the ministry has issued an appreciable number of new diamond mining licenses in the Northern Province – about 60 in *Bombali* District by late 2004, 18 in *Kambia* District and two in *Port Loko*. Many others are in the works, and by the end of 2004, an estimated 16 dealer-agents and four dealers had set up shop in the area. [4]

3.1.1 Exploration and mining

Following, only middle- and large-scale mines will be mentioned, due to the fact that artisanal and small-scale diamond mining activities are widespread in the *Kono* District as well as *Kenema, Bo,* and *Pujehun* Districts. About 1,700 artisanal mining licenses are currently operating in these areas [4].

The two big players in large-scale kimberlite diamond mining in Sierra Leone are Koidu Holdings S.A., wholly owned by BSG Resources Ltd, and Stellar Diamonds PLC, a London (AIM:STEL) listed diamond mining and exploration company.

Koidu Holdings S.A was granted a 25-year Mining Lease (ML 6/95 ('KKP ML')) over the 4 km^2 Koidu Kimberlite Project, which hosts 2 kimberlite pipes (Fig. 3.3) and at least 4 kimberlite dyke zones. The company also holds the Exploration Licence for the Tongo Diamond Field Project, and have applied for a mining lease to commence operations there.

At the Koidu Lease, a geological model for No. 1 Pipe was created by incorporating in-pit geological mapping, as well as core drilling data from three phases of drilling undertaken in

2003, 2006 and 2007. In total, 26 drill holes measuring 8,116 m were drilled at No. 1 Pipe, delineating the pipe to a depth of 471 m below surface (i.e. elevation of -80 m below mean sea level).

A geologic model of Pipe 2 was based on two phases of drilling in 2003 and 2007, with 20 drill holes totalling 5,507 m, as well as in-pit geological mapping. The resources extend from the current open pit floor at approximately 325 m amsl (above mean sea level) to -165 m bmsl (below mean sea level), a depth of 490 m.

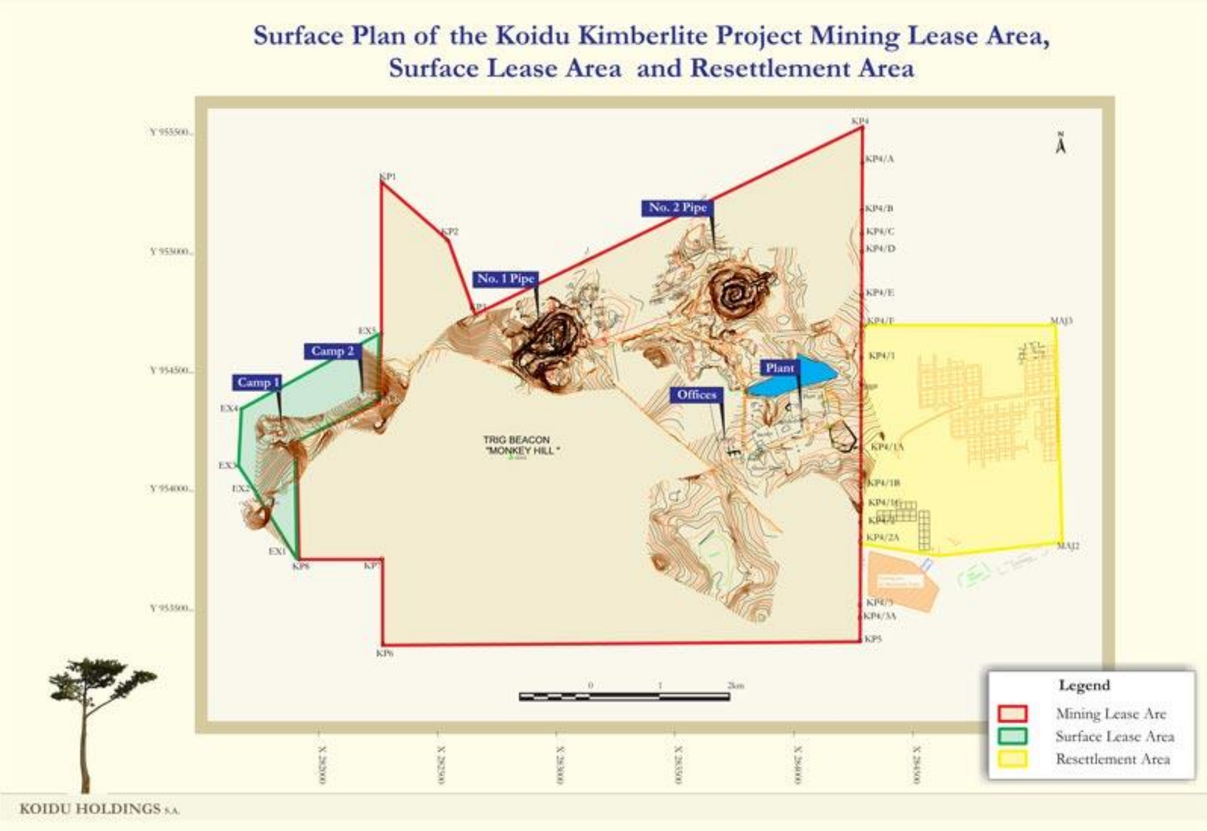

Fig. 3.3: Surface Plan of the Koidu Kimberlite Project - Koidu Holding Ltd. [21].

Dyke Zone A Blow is a small kimberlite pipe measuring approximately 330 m² in surface area and was drilled to a depth of 160 m below surface in 2007. A bulk sampling programme commenced in November 2007, with 6,644.980 carats being recovered from 12,061 t and a grade of 0.55 ct/t.

The small blow on Dyke Zone B measures approximately 900 m² where exposed in the ramp to No. 1 Pipe vertical pit and was drilled in 2007, with 10 drill holes totalling 1,165 m delineating the blow to a depth of 160 m.

These models lead to estimated reserves of 6.3 million carats at *Koidu*.

At the Tongo Lease, Koidu Holdings S.A. obtained an exploration licence (EXPL 4/04) over an approximately 88 km² portion of ground in the *Lower Bambara* Chiefdom (*Kenema* District, Eastern Province of Sierra Leone) in May 2004 (Fig. 3.5). The *Tongo* Field exploration licence area contains four historically documented and sampled diamondiferous kimberlite dyke zones (*Kundu*, *Lando*, *Tongo* and *Peyima*) and a blow at *Peyima*. In addition, the distribution of diamondiferous gravels associated with the drainage patterns suggests that other kimberlite sources could exist within the licence area. In 2008, Koidu Holdings was formally notified that its application for a mining lease over the 88.6 km^2 Tongo Diamond Field Project had been approved by the Minister of Mineral Resources. The Company completed the exploration and bulk sampling program in accordance with the obligations set out in the Exploration Licence and immediately commenced with mining feasibility studies. The results of these studies indicate that a dyke mining operation would be economically viable, despite the narrow dyke widths. The mining lease is for a period of 25 years and includes diamonds, gold and base metals. The exploration leads to estimated reserves of 3.2 million carats. [21].

Stellar Diamonds PLC's *Kono* properties are situated within the renowned *Koidu* diamond mining district in eastern Sierra Leone. Stellar commenced exploration on the 200 km^2 licence areas in 2002 and discovered a number of high-grade diamondiferous kimberlite dykes. Some of these dykes represent the on-strike extensions of the Koidu Holdings Mine, where an indicated and inferred diamond resource of over 2 million carats has been established. Some six shafts have been sunk into different kimberlites where samples were recovered for diamond testing. The trial mining became focused on two of these shafts, Pol-K and Bardu where development drives and trial stope mining have been undertaken. Many more kimberlites still remain to be tested.

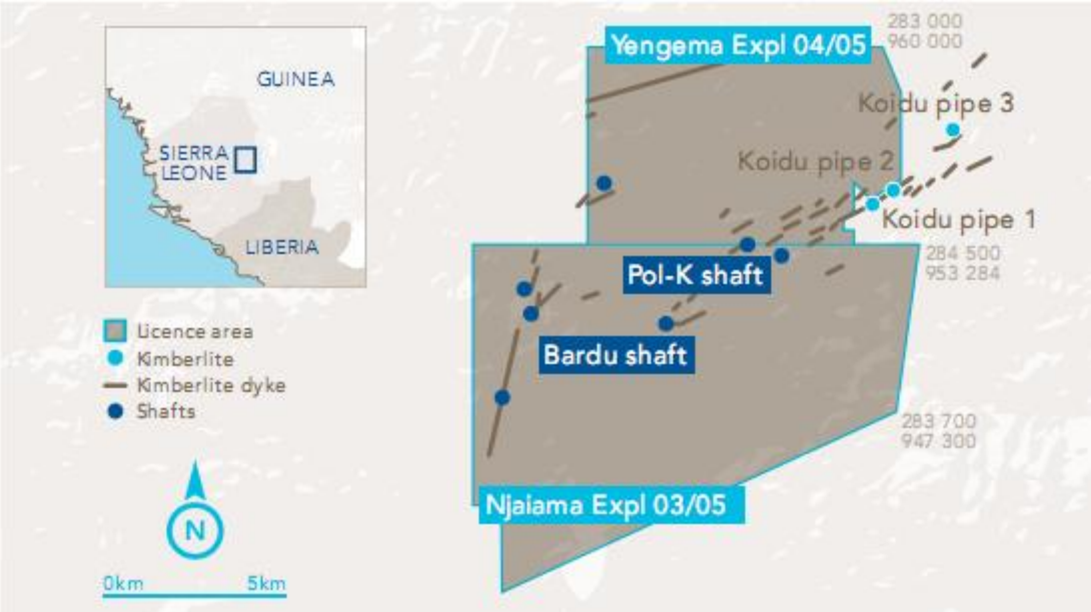

Fig. 3.4: Stellar Diamonds PLC's Kono Properties in the Koidu mining district [27].

At Pol-K the first trial mining stopes have been opened at the 65m level below surface (Level 1). The shaft is currently at 85 m below surface and at a depth of 95 m the second level of stope faces are planned to be developed. At the 30 m level an advance drive was opened up and the dyke traced for 173 m in the south west direction and 94 m in the north east direction. The kimberlite keeps a relatively consistent width of between 60 cm and 70 cm. Based on the presence of artisanal diamond mining, surface mapping and IKONOS satellite imagery the Pol-K kimberlite is estimated to have a strike length in excess of 5 km, so there is considerable scope for the sinking of additional shafts. The in-situ grade of Pol-K has consistently been around 65 cpht. Taking into consideration the mining dilution the “run of mine” grade has ranged between 30 cpht and 40 cpht. The largest diamonds produced from Pol-K weight 11.95, 11.45 and 10.55 carats.

The *Bardu* shaft is currently at a depth of 45 m. The width of the fissure is relatively consistent at 90 cm to 100 cm, though at 100 m to the south west of the shaft the kimberlite opened to a width of 3 m representing a localised swell. This narrowed to 1.5 m at 115 m from the shaft where the current development drive reached. The grade of *Bardu* ran at approximately 65 cpht to 75 cpht. However, the swell has yielded significantly higher grades at 140cpht with better quality diamonds being clearly evident. This is a new kimberlite zone which requires further development to assess its continuity. The largest diamonds from *Bardu* to date weigh 4.4, 2.90 and 2.65 carats.

A total of 4,213 carats of diamonds (+1mm) have been produced (as at 30 April 2010). Of these, Pol-K has yielded 3,209 carats and *Bardu* 867 carats. The balance of diamonds came from other kimberlites that were tested, but have not yet been developed further.

Stellar Diamonds’ *Tongo* property (100 % owned by Stellar Diamonds’ subsidiary company Sierra Diamonds Limited) comprises a single Exploration Licence (EXPL05/07), covering 33 km^2. The EXPL lies on the eastern extension of the diamondiferous *Tongo* dykes in the heart of the well-known Tongo Diamond fields. To the southwest, Koidu Holdings owns the adjacent property and has bulk sampled some dykes yielding grades of between 200 and 300 cpht.

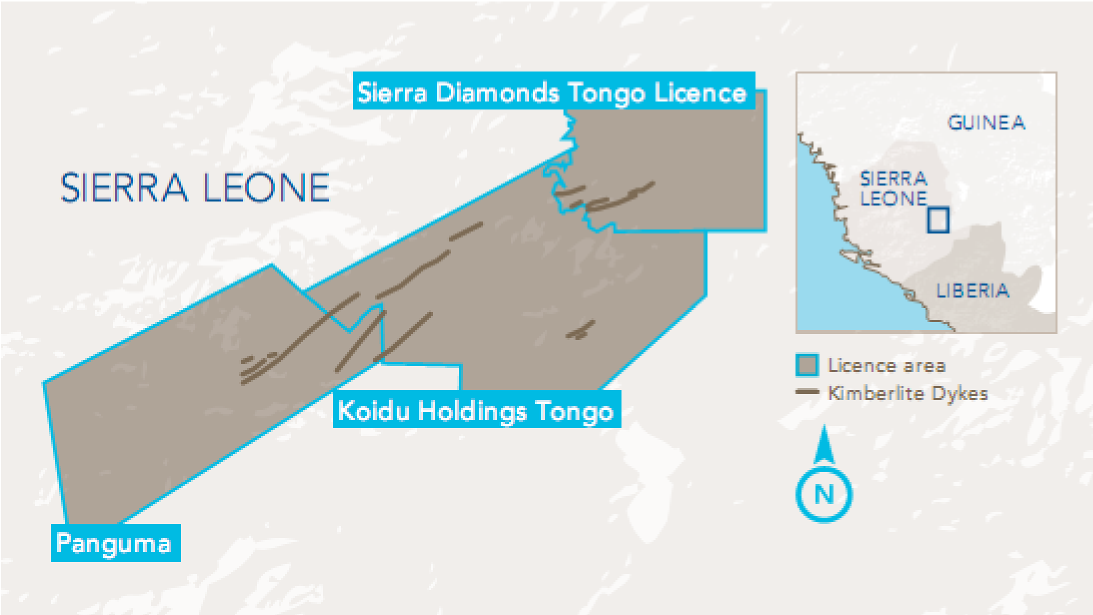

Fig. 3.5: The Stellar Diamonds and Kono Holding Tongo Mining Leases [27].

Stellar has delineated four diamondiferous kimberlite dykes, with thicknesses up to 1 m, through mapping, sampling, ground geophysical surveys and drilling. These are designated Dykes 1 to 4 going from south to north. Dyke 1 has a mapped length in excess of 2.5 km and the potential for further extensions on all dykes is not unrealistic to assume. Work conducted by Stellar to date includes the collection and processing of some 24 mini-bulk samples of up to one tonne in the early exploration phase. These samples gave very encouraging results in that diamonds were present in most samples and grades of up to 385 cpht were calculated. Two surface samples from Dyke 1 and Dyke 4 were excavated by hand from depths of around 10 m. Dyke 1 comprised very competent and fresh kimberlite with a width of between 70 cm and 100 cm. Dyke 4, however, was strongly decomposed and as a result was more difficult to sample. Due to the impact of the rainy season no samples were collected from Dykes 2 and 3. Both mini-bulk samples were initially stockpiled and then trucked to the diamond processing plant at Kono where they were treated separately, giving grades of 90 cpht and 100 cpht for Dykes 1 and 4 respectively. Encouragingly of the 130 carats recovered from Dyke 1, some eight stones were larger than one carat, with the largest stone weighing 4.8 carats. Collection of the bulk sampling from the surface is ongoing and should be complete, with full results, by the end of Q4–10. These results will determine the next phase(s) of work which are likely to comprise shaft sinking and underground trial mining, similar to that conducted at *Kono*, during the course of 2011 [27].

Recently, ***AMR – Minerals Mining Company*** discovered two kimberlite dykes in width of more than 1 m northeast of Pipe 3 in the ***Fiama*** Chiefdom with the following resources: measured 5,015 carats, indicated 7,648 carats., inferred 59,101 carats, and estimated

561,000 carats. Exploration is ongoing. Excavation by AMR was carried out on the dykes at four locations to depths of 7-8.5 m covering about 900 m of strike. The dyke is an extension of one of the six known *Kono* kimberlite dykes (Fig. 3.6). The findings prove that all *Kono* dykes and pipes extend into north *Fiama*. Development of kimberlite pipes of significant size at *Fiama* is also possible, given that such pipes have been located and mined along strike to the southwest. AMR believes that the north *Fiama* concession contains six kimberlite dykes and undiscovered pipes. Their *Fiama* North 2 kimberlite target area covers approximately 45km^2.

At ***Nimikuru***, north-west of *Koidu*, AMR believes that their concession contains 4 kimberlite dykes and undiscovered pipes with an average grade of 0.3 ct./t. They estimate the resources with 250,000 carats [23, 24].

Alluvial diamond deposits are mined by mining companies, as well as artisanal miners in the *Kuido* and *Tongo* area and along the Rivers *Sewa*, *Moa*, and *Mano* and their antecedents. Here, only an excerpt of different alluvial diamond mining companies is given.

The *Bambaya* and *Sowadu* diamond projects are situated in AMR's *Fiama* exploration licence, east of *Koidu* (Fig. 3.6).

ARM's Tefaya gold and diamond lease encompasses an area of 0.15 km^2 on the riverbank and terrace of the *Bafi River* (Fig. 3.7) [24].

ARM's Kathumpeh diamonds project close to *Kamakwie* in the upper reaches of the *Makoti River* drainage in the *Sella Limba* Chiefdom (Fig. 3.8) [24].

African Minerals (formerly known as Sierra Leone Diamond Company, SLDC) purchased African Gold and Diamonds SA's mining plant and equipment at *Tefaya* in the *Kono* district of Sierra Leone. The plant was subsequently renamed in "Konama mine" LDC'S alluvial operations are currently focused in the *Kono* district of Sierra Leone, along the *Middle Bafi River* area and centred around the town of *Tefaya*. [28].

The *Hima* License (EPL 1/94 - **Cream Minerals and Casierra** Development Fund) area lies some 10 km north-east of the town *Sumbuya*, is some 10.5 km long and 1.8 km wide and contains the present course of the *Sewa River* along with adjoining flats and terraces.

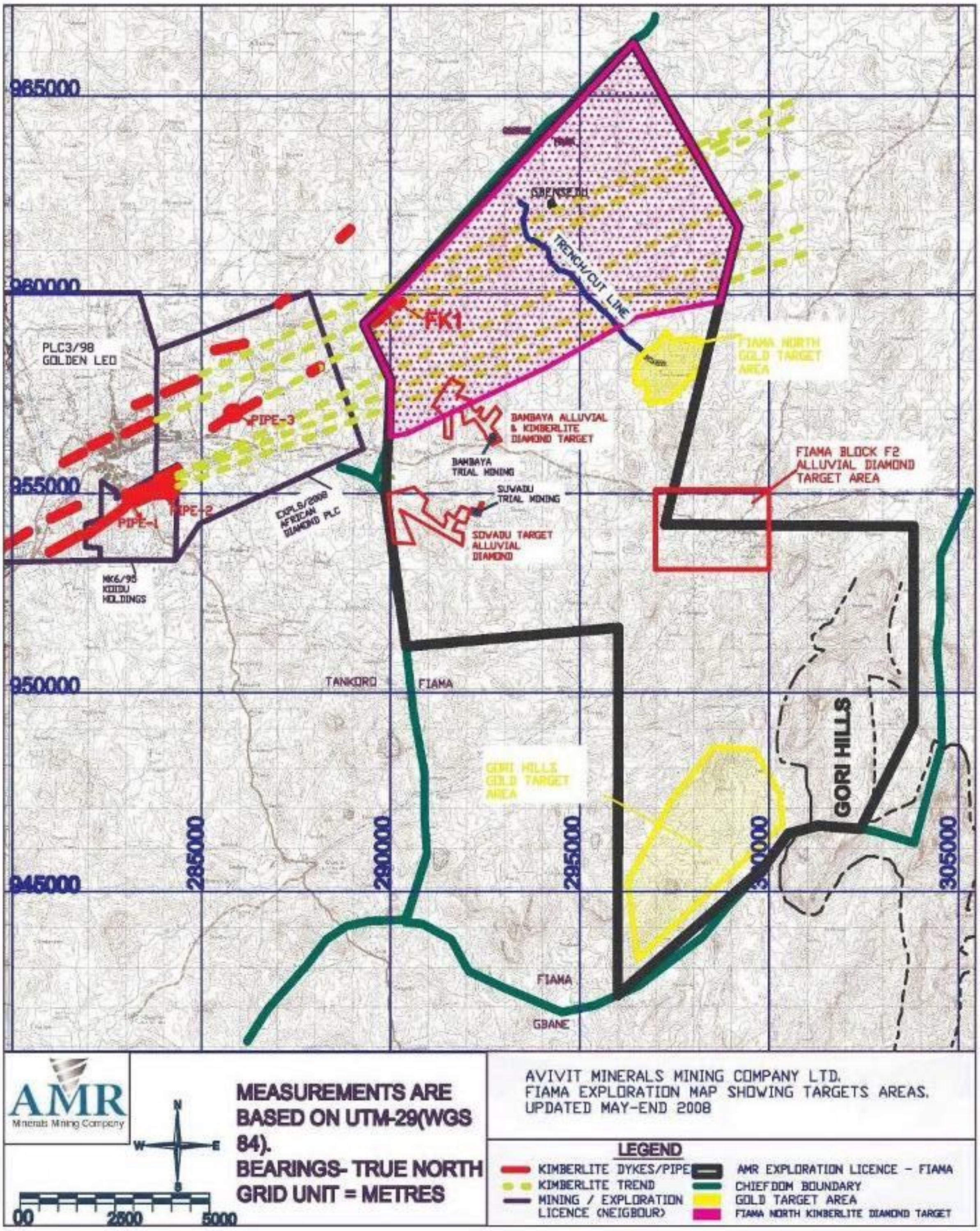

Fig. 3.6: Avivit Minerals Mining Company (AMR) Fiama Exploration Map [24].

Within the licence area the river has a relatively low gradient but is bounded both upstream and downstream by sections of the river with much steeper rapids forming gradients. The licence area therefore appears to be a depositional portion of the river resulting in deeper overburden on the terraces and with little or no exposure of gravels within the river course itself. These factors have limited the amount of hand mining, which could be carried out by local or artisanal miners on the licence. [29].

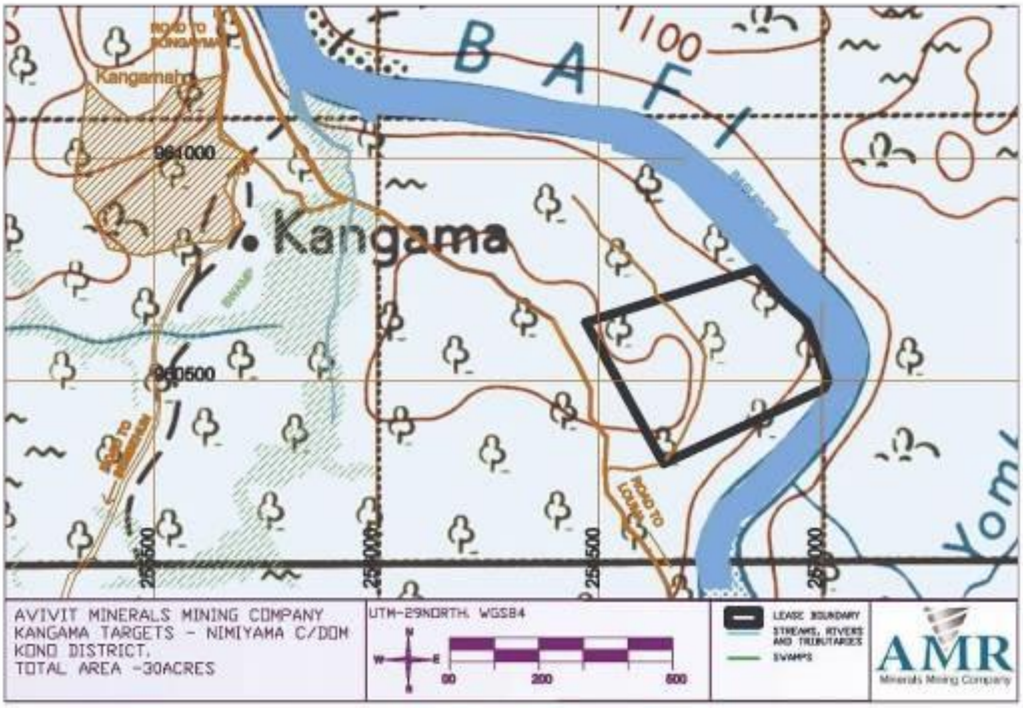

Fig. 3.7: Avivit Minerals Mining Company Tefaya gold and diamond exploration target [24].

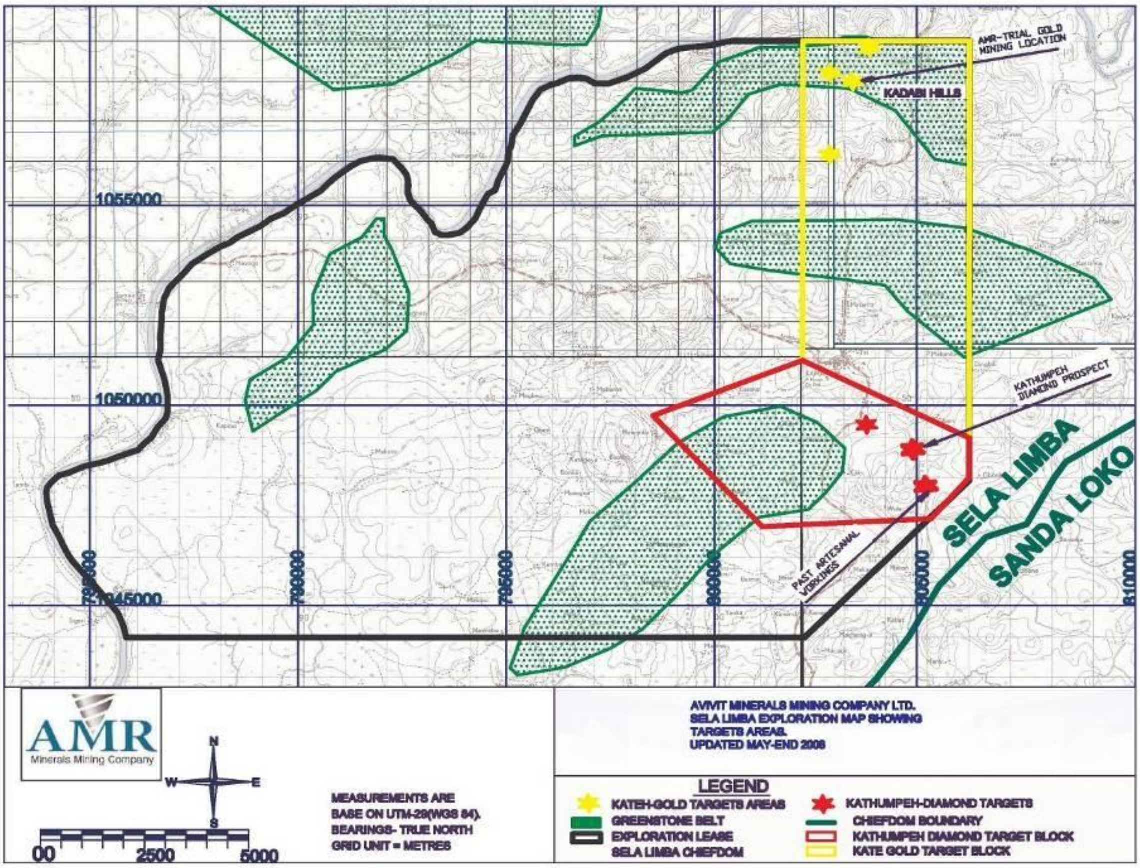

Fig. 3.8: Avivit Minerals Mining Company Kathumpeh diamond and Kate gold exploration target [24].

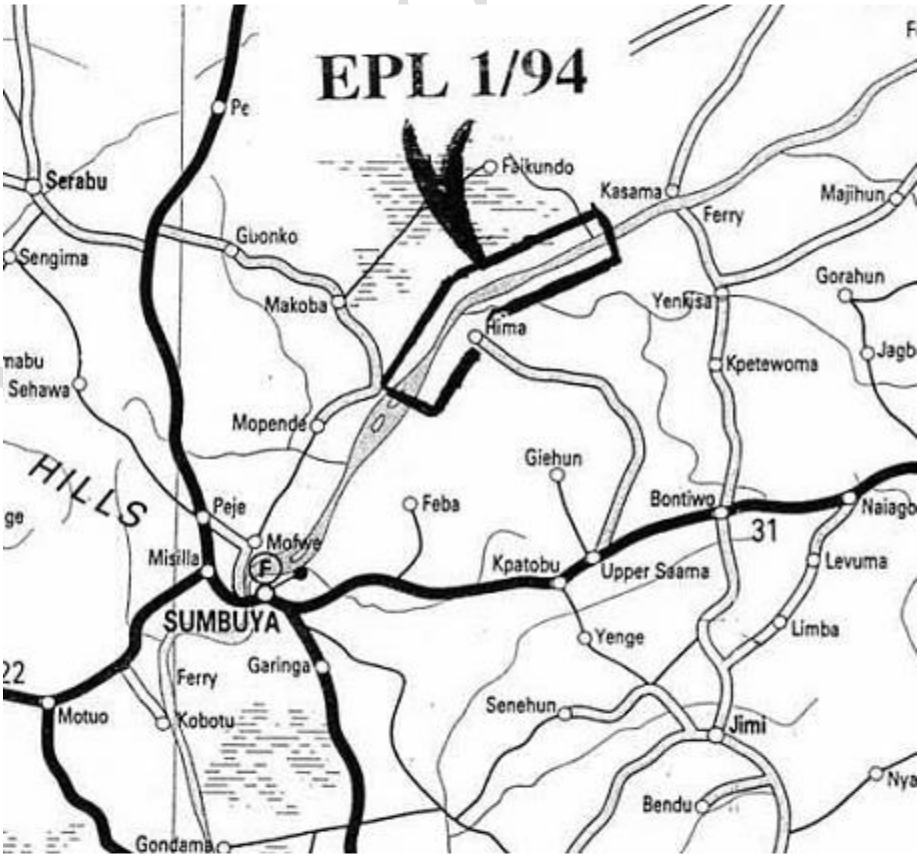

Fig. 3.9: Location of the Hima License (EPL 1/94 - Cream Minerals and Casierra Development Fund) [29].

3.2 Gold

Gold was discovered in several localities in the years from 1926, in the *Sula Mountains* and *Kangari Hill*s, and in the *Koinadugu*, *Tonkolili* and *Bo* Districts.

All greenstone belts in Sierra Leone (with the possible exception of the *Marampa* Group and perhaps the *Kambui Hills*) are known to contain gold. Rivers and streams draining these areas also carry gold. Prospecting activities by the Geological Survey established the existence of gold in the following localities within the granite-greenstone terrain of Sierra Leone:

- The *Sula* Mountain area including Lake *Sonfon*, *Maranda* and *Yirisen*.
- The *Kangari* Hills area especially *Baomahun*, *Makong* and *Makele*.
- The *Nimini* Hills
- The *Loko* Group Schist belt in the *Kamakwie-Laminaia* area, northern Sierra Leone
- The *Gori* Hills.

The most important known lode gold deposits occur around the Lake *Sonfon* area, *Kalmaro*, *Makong*, *Baomahun* and *Komahun*.

The Lake *Sonfon* area contains steeply dipping quartz and pegmatite veins showing sulphide mineralization and with gold assay values of up to 0.67 oz/t. Gossanous floats assaying up to about 3 oz/t were also found. At *Kalmaro*, mineralized quartz veins and lenses intruding talc-chlorite-carbonate schists have been traced for about 800m strike length, assaying up to 0.8 oz/t.

In the *Makong* area, quartz veins, veinlets and stringers, sometimes with megascopically visible gold, occur in the upper reaches of the *Kwifwi* stream. Further exploration in the *Makong* area revealed an extensive system of mineralized quartz veins in en-echelon arrangement.

At *Baomahun*, the gold mineralization is also associated with sulphides and follows the contact between magnetite rich garnet-cummingtonite schists and cordierite schists. The contact zone is about 100 m wide and extends about 1.5 km. The *Baomahun* deposit was divided into three areas by the Geological Survey, namely Eastern, Central and Western with an estimated reserve of about 1-2 million ounces of gold.

At *Komahun* in the *Nimini* Hills greenstone belt, significant gold mineralization occurs over an area of about 400 m x 100 m. Drill core assay values of up to 1 oz/t and averaging about 0.25 oz/t over 20 m were obtained [4, 30].

In recent times (2010), the only gold production in Sierra Leone comes from alluvial deposits. Artisanal and small-scale gold mining activities are predominant in the *Tonkolili*, *Bombali*, *Koindugu* and *Kono* Districts.

3.2.1 Exploration and mining

Cluff Gold's flagship Baomahun is a development-staged project in Sierra Leone, wholly owned by the Company. The existing resource base, consisting of 1.4 Moz Au in measured and indicated resources and 1.0 Moz Au in inferred resources, is hosted in an area of approximately 2 km^2, while the total project licence area is 136 km^2. *Baomahun* is located in the *Bo* district in the Southern Region of Sierra Leone, approximately 180 km east of the Sierra Leone capital *Freetown* (Fig. 3.10). The nearest large town is the provincial capital *Bo*, located approximately 60 km south of the Project and 250 km from *Freetown*. The project area is comprised of the *Baomahun* Mining Lease, which covers an area of 59.85 km^2, and the adjoining Victoria Exploration Licence, which covers an area of 77.45 km^2.

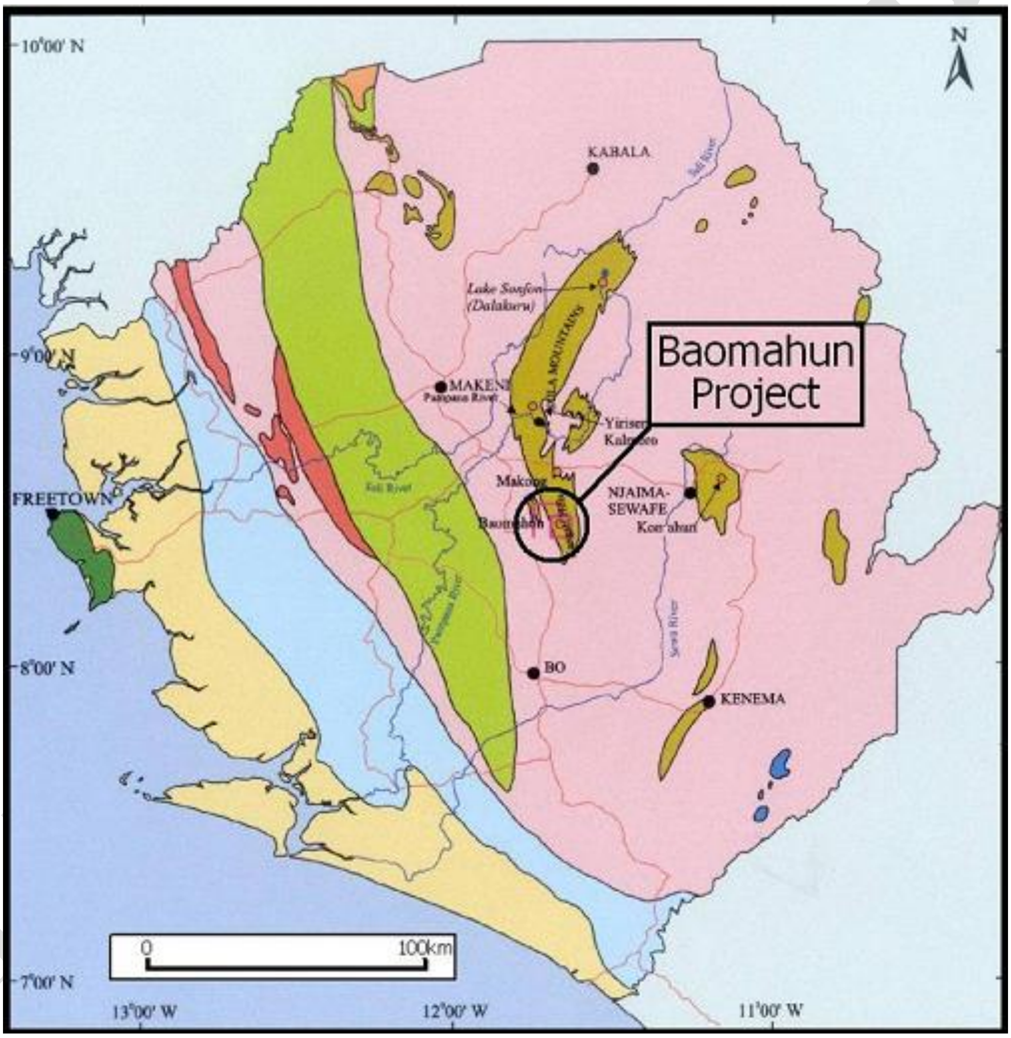

Fig. 3.10: General Location of the Baomahun Project (Cluff Gold) in relation to the regional geology of Sierra Leone [32].

The current resources all lie within the Mining lease which was granted in 2008 for a period of 25 years.

The geology of the Project area comprises predominantly meta-sedimentary suite rocks characteristic of the southern tip of the *Sula* Mountains/*Kangari* Hills Belt. The deposit itself

comprises a series of steeply dipping zones of sulphide mineralization in the form of pods and lenses which trend approximately north-northwest along the slopes of the southern limits of the *Kangari* hills and extend over a total strike length of approximately 1.5 km. The main sulphide minerals encountered are pyrrhotite, arsenopyrite, and pyrite. The top of the zones are covered by a relatively thin, generally less than 20 m, layer of oxidised material.
The mineralization appears to be particularly localised in metasediments adjacent to metre-decimetre scale banded iron formation (BIF) units. Typically the host rocks to the mineralization are a series of garnet-mica and quartz-mica schists and which vary from a few metres to 40 m in thickness. BIF units appear to play a central role in localising mineralization. They do not normally host mineralization, except when they are sheared or occur as intercalation with the other rock types but, as noted above, appear to have acted as rigid objects within a less viscous rock matrix, resulting in the concentration of mineralization adjacent to their contacts. In fact, BIF has been used as marker horizons by local artisanal miners to locate mineralised zones within the oxidised areas normally within 20 m of surface. Currently, the resource area to date is comprised of three zones: The Eastern Zone, the Central Zone, and the Western Zone.
Baomahun currently hosts 1,420,000 oz of gold in the measured and indicated categories, at an average grade of 2.9 g/t, with an additional 1,030,000 oz of gold in the inferred category, at an average grade of 2.6 g/t [31, 32].

AXMIN's Komahun Gold Project within the *Nimini* West and *Nimini* East licenses, collectively known as the *Nimini* Hills property, are situated in the central west *Kono* region of Sierra Leone, some 330 km east of the capital *Freetown* (Fig. 3.11). Both licences are held by AXMIN Inc in joint venture with *Nimini* Hills Mining Company (a 75 % owned subsidiary of Eldorado Gold Corporation). The *Nimini* Hills property is held under two exploration licences. The *Nimini* East Exploration licence (Number EXPL 01/08 44 km²) is valid from 1st November 2007 for a period of two years. The *Nimini* West Exploration licence (Number EXPL 4/06, 56 km²) was issued on August 11, 2006 for two years and is currently under the renewal process to extend exploration rights to 2010 after which a two year extension is anticipated. These permits give AXMIN the right to explore for gold, diamonds, associated minerals and base metals. The total area of the two permits is approximately 100 km^2.
The *Nimini* Hills consist of a 2–8 km wide, northeast trending greenstone belt with granitoid rocks to the east and west. The belt is thicker where it has been folded about north-south axes.

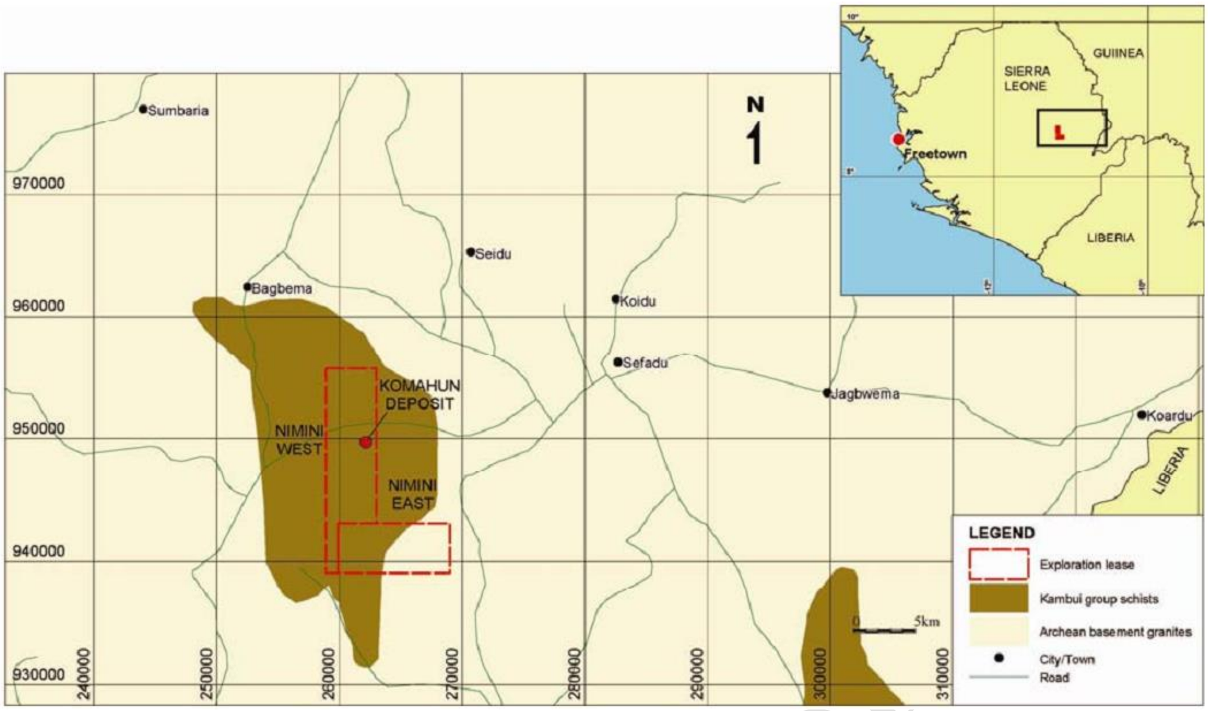

Fig. 3.11: Location of the Komahun deposit and the Nimini Hills Licences (AXMIN) [33].

The majority of the greenstones comprise a sequence of metamorphosed ultramafic and mafic units interbanded with sedimentary rocks, including banded ironstones, which are thought to belong to the lower part of the late Archaean *Kambui* Supergroup. AXMIN's airborne magnetic and radiometric survey indicates that the northern third of the *Nimini* West licence is underlain by metasediments of the upper part of the *Kambui* Supergroup. The summits of the hills are typically capped by ferricrete. The units have been repeatedly folded and sheared. Gold is associated with quartz-sulphide veins and disseminated sulphides within a 50 m wide, northeast-southwest trending shear zone mineralization which is sub-parallel to lithology and is predominantly in unweathered sulphide material.

The *Nimini* Hills property currently hosts 110,000 oz of gold in the indicated category, at an average grade of 9.1 g/t, with an additional 435,000 oz of gold in the inferred category, at an average grade of 4.3 g/t [33].

Aureus Mining's Sonfon Gold Project is currently being explored by Golden Star Resources (GSR). A 3,000 m core drilling programme is completed – results pending. Significant regolith gold anomalies (>160 ppb Au, with high values up to 9,963 ppb Au) occur in north-south structures over a 10 km strike length at *Sonfon* (Fig. 3.12). The majority of regolith mapped in this area is considered to have formed in situ and it is expected that bedrock mineralization may occur in close proximity to the surficial gold anomalies. This is further supported by the strongly anomalous rock-chip samples (three samples contained 2.25, 2.67 and 7.05 g/t Au) that have been taken in close proximity to the gold-in-soil anomalies[34, 35].

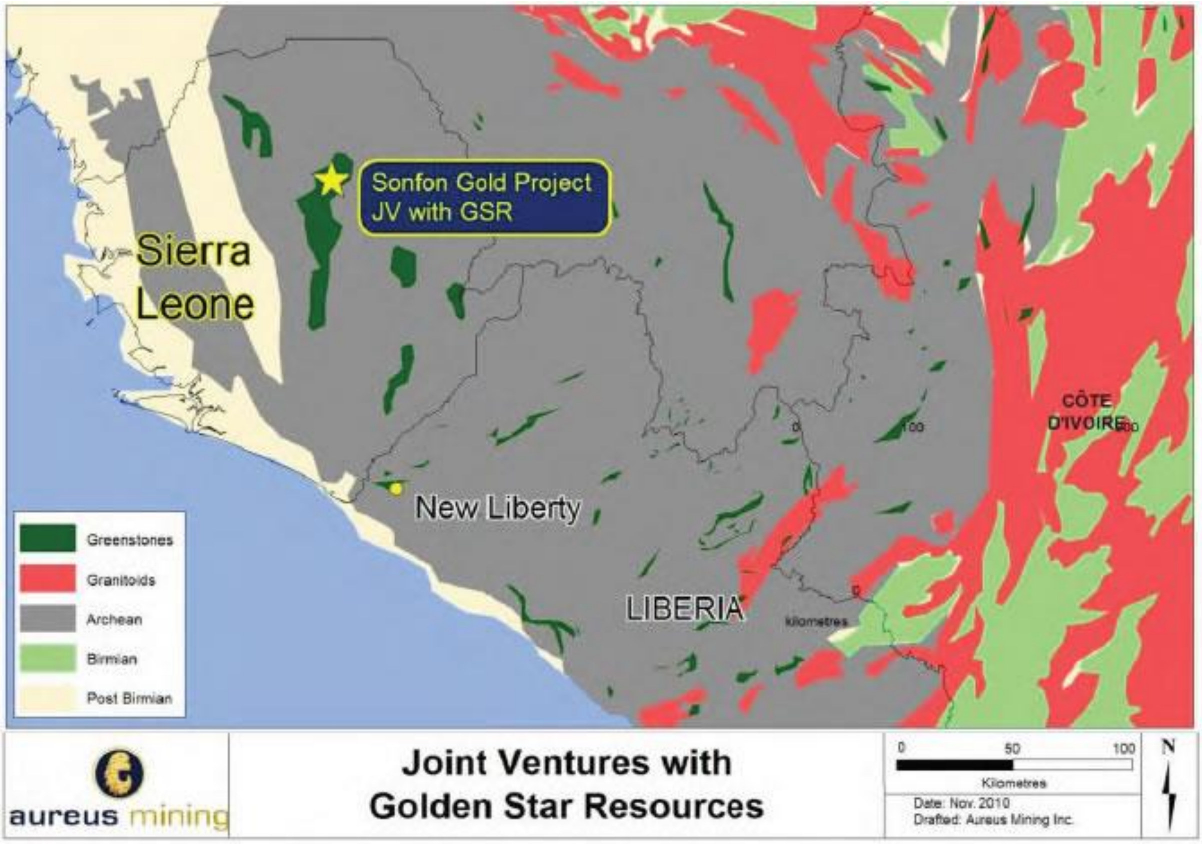

Fig. 3.12: Location of Aureus Mining's Sonfon Gold Project [34].

AMR Minerals Mining Company owns beside its diamond leases also several leases for gold exploration and mining. These are the ***Laminaya gold project*** (aka *Loko* Group gold mine in the *Kamakwie-Laminaia* area, aka *Sando Loko* gold) in the *Sando Loko* Chiefdom, the ***Kate Gold Project*** at *Kateh* in the *Sella Limba* Chiefdom, and the ***Gori Hills*** gold projects in the *Fiama* Chiefdom, east of *Kuido*, the ***Tefaya Gold Project*** in the *Sandor* Chiefdom [24].

The ***Kate Gold Project*** covers an area of 12 km^2 in northern Sierra Leone, centred 7 km north of *Kamakwie* (Fig. 3.8). The central prospect lies in a narrow swamp rising on both sides up the slopes of the *Kadabi* Hills which comprise part of the granite/greenstone terrane of the *Loko* Group. The main rocks of the region comprise basement granites, gneisses and migmatites of the pre-Leonean age craton. The granites are homogenous, pink in colour and coarse grained and are composed of quartz, feldspar and biotite, with accessory garnets, tourmaline and iron minerals. Gold and cassiterite mineralisation are associated with portions of the *Loko* Group, most likely quartz veins related to a late Leonean granitisation event which accompanied the formation of major shear zones. At *Kamakwie* a number of discrete greenstone belt outliers with a general north-northwest orientation are mapped, many of which appear to have a direct relationship to known alluvial gold deposits. These include the

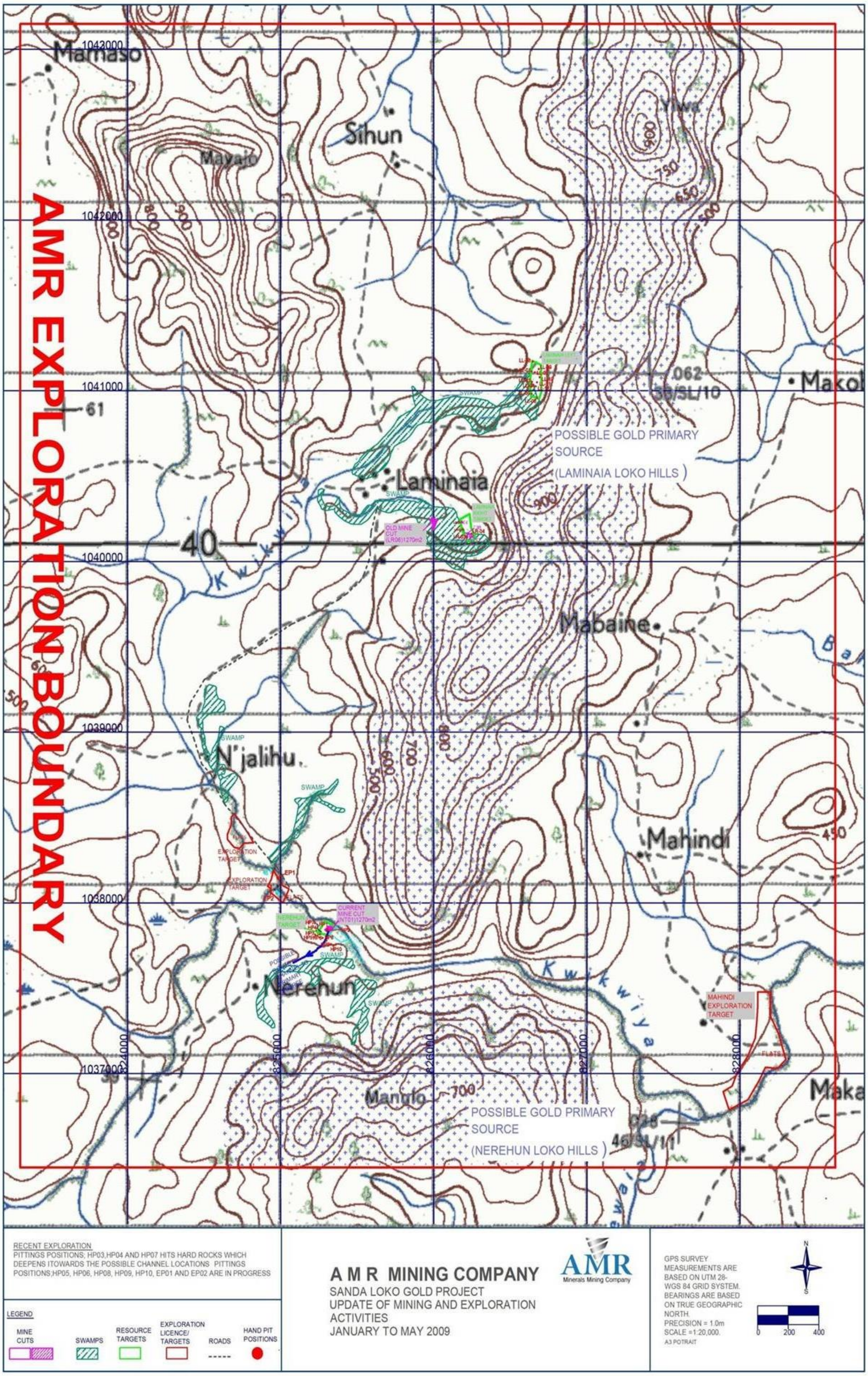

Fig. 3.13: Location of the Sando Loko gold project, aka Laminaya gold project (AMR) [45].

Laminaia area, 22 km southeast of *Kamakwie*, where gold was initially discovered in the region in 1931, the *Kasasi* area, 15 km northeast of *Kamakwie* and the *Kate* area.
Artisanal gold mining is continuing in the *Kamakwie* region up to the present time. The AMR principals have supported up to 100 licensed artisanal miners in the *Kate* area – the Ministry of Mineral Resources confirms the purchase and export of 333.69 oz gold between March and May 2006. The *Kate* deposits estimations are: Grade: 3.43g/t Au; Indicated: 93,000 oz.; Inferred: 279,000 oz.; Estimated: 100,000 oz. [23].
The ***Tefaya Gold Project*** is located in the *Kono* region, approximately 10 km west of *Koidu* town (Fig. 3.7). Alluvial gold is thought to be sourced from the greenstone beds of the *Nimini* Hills, which lie just to the east of *Tefaya* and are cut by the *Bafi* River. Gold grades have not been quantified due to the lack of information on which to base an estimate, but observations suggest that gold recovery could make a useful contribution to the *Tefaya* mining operation.
In the ***Gori Hills,*** alluvial gold was originally recorded by the Sierra Leone Geological Survey area several decades ago. However, comparatively little modern exploration appears to have taken place either for alluvial gold or to locate the bedrock sources of the gold in the *Gori* (Fig. 3.6).
The gold deposit of the ***Laminaya gold project*** (alluvial & primary) is in a wide valley (*Kwikwiya*) surrounding a primary source from the two hills *Mohendi* and *Nerehun*, 22 km southeast of *Kamakwie* (Fig. 3.13). The first exploration area of *Laminaya* is only 10 % depleted, which means that 90 % of the 35.6 km² (32.04 km²) is still intact. 70 % of these are alluvial gold deposit of flat and low terraces as results of drainage from primary source in the two hills. Trial gold mine commenced in *Laminaya* in 2009. A narrow channel, under heavy rock shows very high grades of up to 20 g/t. This channel believed to be a primary source route from the *Nerehun* hills and it is currently under investigation. The inferred resources are 312,311 oz, the estimated 1,295,890 oz [23, 24].

3.3 Titanium – Rutile and Ilmenite

Rutile is a high-grade titanium ore, which is processed into titanium dioxide for use mainly in paint, paper and welding rods. Sierra Leone is known for its particularly high-grade rutile. Titanium has a wide range of applications and is the metal of choice for the rapidly-growing aviation industry. In the medium-term, demand for the metal is expected to continue to be driven by the Chinese commodity boom.
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*** Deposit
- the ***Sembehun*** Deposit
- the ***Rotifunk*** Deposit
- the ***Kambia*** Deposit

Sierra Leone has the largest natural rutile reserves in the world and was accordingly the largest producer of natural rutile worldwide, accounting for a third of the total world production.

Rotifunk

The *Rotifunk* mineral sands prospect is the second largest known mineral sands deposit in Sierra Leone (after TRG's Sierra Rutile mine). It is located 65 km southeast of *Freetown* and lies approximately 40 km northwest of the Sierra Rutile mine. During the years 1970 to 1976 the German companies Bayer AG and Preussag AG explored, both, off-shore and on-shore, for rutile and accompanying heavy minerals in Sierra Leone. The geologic feature of the *Rotifunk* deposit is unique in comparison with other occurrences of titanium minerals. The quaternary placer is located in the range of a metamorphic belt in the western part of the country. Characteristics are a short mechanical transport, poor sorting and post-sedimentary weathering. [36]. The deposit has an outline of an inverted Y-shape 0.5- 2 km wide and 12 km long close to *Rotifunk* Town approximately 60 km distance ESE of *Freetown* and 30 km from the coast. An Australian company, Hazecare (PTY) applied for and was granted a Special Exclusive Prospecting Licence (SEPL) in 1990, and re-evaluated the deposits. Records of work undertaken by both Bayer-Preussag and Hazcare have provided mineral resource estimates of 207 million tonnes at 0.49 % rutile and 163 million tonnes at 0.48 % rutile, respectively. The deposit essentially consists of a 6-7 m thick horizon of sandy clay within the *Bullom* Group sediments. A laterite capping 3-5 m thick forms the overburden. The *Rotifunk* rutile deposit also contains about 2 million metric tons of ilmenite and 125,000 t of zircon. [30, 37]

Gbangbama

Late Quaternary infillings of post-Cretaceous valley systems by alluvial and eluvial processes have led to the concentration of heavy and resistant minerals derived from the weathering of the Archean *Kasila* Group granulites and amphibolites. In the *Bonthe* and *Moyamba* districts these heavy mineral concentrates have been derived from the *Gbangbama* hills and their northern extensions. East of these hills the heavy minerals include concentrations of rutile, ilmenite, and zircon which were deposited into shallow morphological basins nearby. The sediments are poorly sorted with a lack of horizontal bedding and are intensively weathered. The detrital material has apparently been deposited from sheet-wash during periodic heavy rains, as fanglomerates under more arid conditions than are found today. To the west of the *Gbangbama* hills deposition appears to have been periodically lacustrine in character near to the sea shore and contains lignites of late Würm to Holocene age. The rutile content of the sediments is high [8, 39].

The ***Gbangbama*** group consists of at least six major deposits: *Mogbwemo*, *Bamba-Bel*ebu, *Pujubu*, *Lanti*, *Gbeni* and *Gangama*. *Rutile* was mined from the *Mogbwemo* deposit by Sherbro Minerals from 1967 to 1971.

Sembehun

The *Sembehun* group is also made up of six deposits, namely: *Kibi*, *Dodo*, *Benduma*, *Komende*, *Mokamatipa* and *Matehun*. General exploration which started in 1990, revealed the presence of over 180 million tons of rutile with grades ranging from 1.2- 1.6 % rutile.

Kambia

Substantial quantities of rutile in the form of coarse crystals occur in the gravels of the *Little Scarcies River*, around the confluence with the *Mabole River* in the *Kambia* District.

3.3.1 Exploration and mining

Sierra Rutile (owned by Titanium Resources Group - TRG, which are LSE-AIM listed) in south western Sierra Leone is thought to be the world's largest known rutile deposit. It holds mining leases of 580 km^2 in which 19 separate rutile deposits have been identified, and was responsible for about 25 % of world production of rutile at the time it ceased production in 1995 due to civil war. Following the cessation of hostilities, Sierra Rutile has restarted production. The probable reserves are 259 million tonnes at 1.48 % recoverable rutile. The company's production is approximately 80,000 t/y of rutile increasing to 200,000 t/y with the second dredge in place and 15,000 t/y ilmenite; Dredge D3 will add up to 40,000 t/y to rutile production capacity. A Foundation Fund has been set up by the Company to mobilize funds for community development projects. [38].

The bulk of the deposits occur in two clusters in the *Gbangbama* hills area; the Area One deposits (ML011/72), and the *Sembehun* area (ML15/72). The deposits are proximal alluvial placers in origin, infilling north-easterly (and north-westerly) trending channels incised during the imposition of the secondary drainage system.

A total of 20 rutile deposits have been identified within the SRL tenements, namely: *Bamba/Beleu* Deposit, *Mogbewmo* Deposit, *Mokula* Deposit, *Ndendmoia* Deposit, *Pejebu* Deposit, *Lanti* Deposit, *Gbeni* Deposit, *Gangama* Deposit, *Taninahun* Deposit, *Gambia*

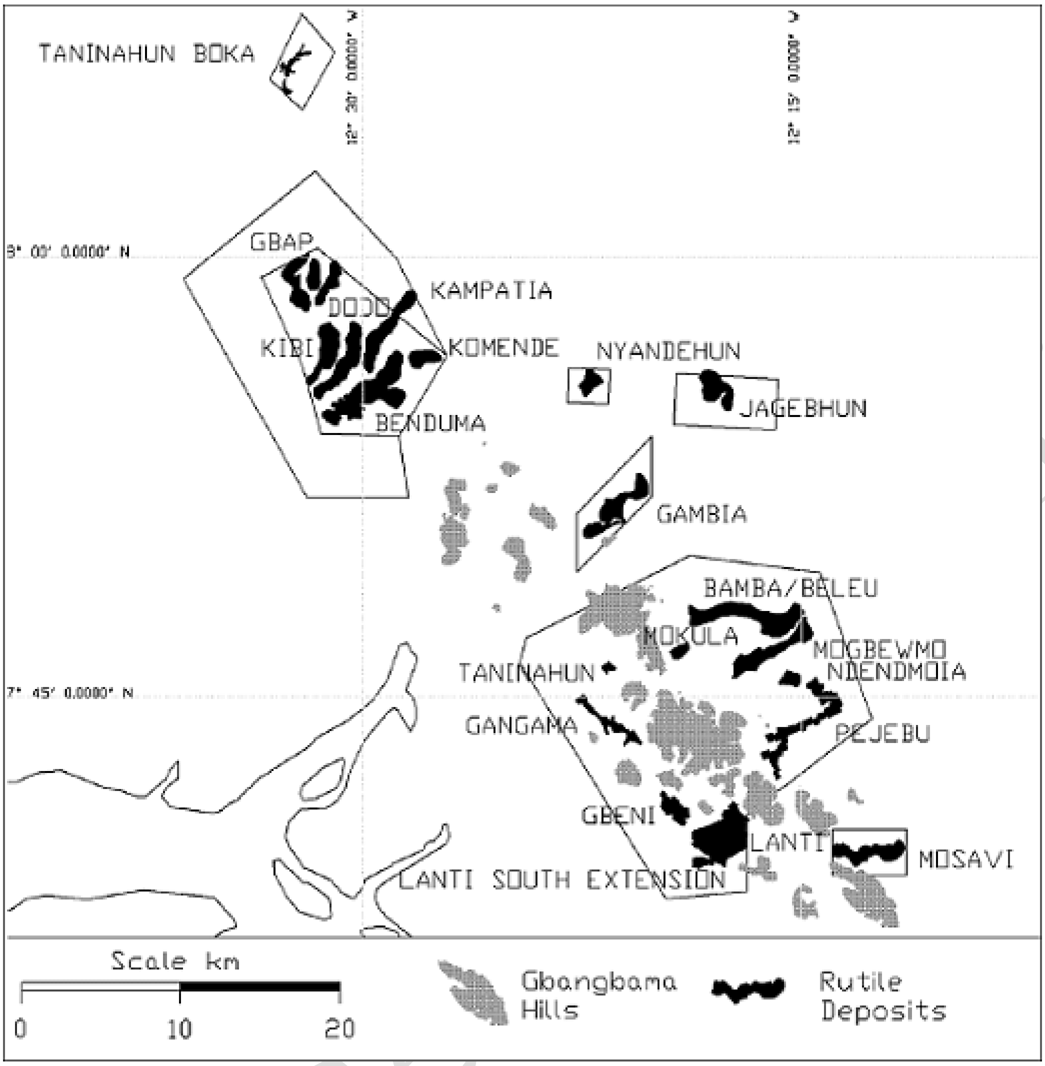

Fig. 3.14: Location of Sierra Rutile's rutile deposits in Sierra Leone [46].

Deposit, *Jagebhun* Deposit, *Nyandehun* Deposit, *Benduma* Depsoit, *Kampatia* Deposit, *Dodo* Deposit, *Kibi* Deposit, *Komende* Deposit, *Gbap* Deposit, *Taninahun Boka* Deposit, and *Mosavi* Deposit (Fig. 3.14). The company has also acquired the rights to mine the *Rotifunk*

4 Conclusions and Outlook

The mining industries sector in Sierra Leone is at a transformative stage in its development. Sierra Leone has a long history of mining and, although relatively small by international standards, the sector is extremely important for the national economy. After the war, the sector has been re-establishing itself, a few existing mines have been re-opened and a large number of exploration companies have been moderately investing in exploration. Since the end of the war, diamond, rutile and bauxite mining have recommenced, and the mining sector is expected to grow with the development of gold and iron ore deposits. The Extractive Industries Transparency Initiative (EITI) along with the Kimberley Process Certification

Scheme (KPCS), the new Mines and Minerals Act (MMA), the proposed Diamond Trading Act and the establishment of the National Minerals Agency collectively form the framework through which Government can effectively manage the sector. [40].
The mining sector was a significant contributor to Sierra Leone's economy; it accounted for about 90 % of export revenues, mainly from diamond exports, and 20 % of the gross domestic product (GDP). Sierra Leone was the world's 10th ranked producer of diamond by volume in 2009 and the world's third ranked producer of rutile [41, 42].
Output levels for most mineral commodities decreased since 2008, due to world-wide economic recession in 2009, with the exception of diamond, which showed an increase of 8 %. The gold production decreased by 17.8 % to 157 kg; ilmenite production decreased by 13.5 %; and rutile production decreased by 19.1 % to 63,864 t, see Tab. 4.1.
Growth in real gross domestic product is expected to recover to 4.5 % in 2010 and to increase gradually to 6 % by 2012 as a result of, among other things, the completion of several infrastructure projects and the recovery of the global economy, which is likely to increase the demand for mineral exports [15].

Tab. 4.1: Production of mineral commodities in Sierra Leone [15].

Commodity	2005	2006	2007	2008	2009
Diamonds [ct.]	668,710	234,440	235,830	254,160	236,240
Gold [kg]	53	71	212	191	157
Rutile [t]	--	73,802	82,527	78,908	63,864
Ilmenite[t]	--	13,819	15,750	17,528	15,161

Notwithstanding its relatively small size, Sierra Leone is widely recognized as a highly prospective target for mining activities. The return to political stability in Sierra Leone coupled with positive global developments in the mining sector now offers the ideal opportunity to rejuvenate the domestic mining sector and to allow it to once again underpin the formal economy and support the Government's developmental objectives.
Positive exploration results, e.g. new diamond findings in the Kamaranka-Kamakwei and the Kambia zones, in the north, AMR – Minerals Mining Company's Fiama kimberlites, and several new gold projects, approve Sierra Leone's extraordinary mineral potential.
Strong mineral potential that remains underdeveloped and underexplored includes proven deposits of bauxite, iron ore, rutile and ilmenite, platinum, chromite, and subordinate columbite. Plentiful resource base and a highly prospective geology for gold, diamonds,

lignite, clays, and base metals like copper, nickel, lead, zinc, molybdenum is in development [43].

Further opportunities for investment in the mining sector are [44, 43]:

- Attractive fiscal and non-fiscal incentives
- Significant Hydro and irrigation potentials
- Easy access to land with smooth facilitation process
- Significant untapped mineral deposits
- 5.5 % GDP growth rate – 2008
- Strong privatization and divestiture program scheduled
- Duty-free access to lucrative markets (USA, EU and Asia)
- Stable Democracy
- Government committed to market-oriented solutions for development.
- Mining sector set to expand rapidly in the near-term driven by an ambitious legal and regulatory reform program to comply with international best practices.
- Anti-corruption initiatives strengthened in 2008.
- Extractive Industries Transparency Initiative ("EITI") candidate country.
- World Bank Doing Business Rankings: improved by 20 places between 2007 and 2010. Ranked ahead of its neighbours in the Mano River Union.
- Member of the Kimberley Process

5 References

[1] Auswärtiges Amt der Bundesrepublik Deutschland – Sierral Leone: Kultur- und Bildungspolitik. http://www.diplo.de/SierraLeone

[2] Foreign & Commonwealth Office, Travel and living abroad – Sierra Leone. http://www.fco.gov.uk/en/travel-and-living-abroad/travel-advice-by-country/country-profile/sub-saharan-africa/sierra-leone

[3] The World Factbook. CIA, 2009. https://www.cia.gov/library/publications/the-world-factbook/geos/sl.html

[4] Sierra Leone Ministry of Mineral Resources. http://www.slminerals.org

[5] "Final Results 2004 population and housing census". Government of Sierra Leone. 2006. http://www.sierra-leone.org/Census/ssl_final_results.pdf.

[6] Renner-Thomas, A. (2010). Land Tenure in Sierra Leone: The Law, Dualism and the Making of a Land Policy. AuthorHouse, pp. 6–7. ISBN 9781449058661.

[7] Schlüter, T. & Trauth, M.H. (2008). Geological atlas of Africa: with notes on stratigraphy, tectonics, economic geology, geohazards, geosites and geoscientific education of each country. Springer, p. 220. ISBN 9783540763246.

[8] Morel, S.W. (1979) The geology and mineral resources of Sierra Leone. Economic Geology, 74, 7, 1563-1576.

[9] Williams, H.R. (1978) The Archaean geology of Sierra Leone, Precambrian Research, Volume 6, Issues 3-4, Pages 251-268.

[10] Rollinson, H.R. (1978) Zonation of supracrustal relics in the Archaean of Sierra Leone, Liberia, Guinea and Ivory Coast. Nature, v. 272, no. 5652, p. 440-442.

[11] Culver, S. J. & Williams, H.R. (1979) Late Precambrian and Phanerozoic geology of Sierra Leone. Journal of the Geological Society of London, 136, 5, 605-618.

[12] Culver, S.J., Williams, H.R. & Bull, P.A. (1978) Infracambrian glaciogenic sediments from Sierra Leone. Nature, London, 247, 49-51.

[13] Encyclopædia Britannica (2011). Sewa River. Retrieved from http://www.britannica.com/EBchecked/topic/536864/Sewa-River

[14] Anonymous (1960) Geological map of Sierra Leone, Scale ca. 1:1,000,000. Sierra Leone Geological Survey Department, Freetown.

[15] Bermúdez-Lugo, O. (2011) The Mineral Industry of Sierra Leone. USGS Minerals Yearbook 2009.

[16] Janse, A.J.A. & Sheahan, P.A. (1995) Catalogue of world wide diamond and kimberlite occurrences: a selective and annotative approach. J. Geochem. Explor., 53, 73-111.

[17] Thomas, M.F., Thorp, M.B. & Teeuw, R.M. (1985) Palaeogeomorphology and the occurrence of diamondiferous placer deposits in Koidu, Sierra Leone (in Placer deposits) Journal of the Geological Society of London, 142, Part 5, 789-802.

[18] Williams, H.R. & Williams, R.A. (1977) Kimberlites and plate-tectonics in West Africa. Nature, 270, 507-508.

[19] PAC (2006) "Diamond industry annual review: Sierra Leone 2006", Partnership Africa Canada. http://www.pacweb.org/Documents/annual-reviews-diamonds/SierraLeone_AR_2006-eng.pdf.

[20] Barth, M.G., Rudnick, R.L., Horn, I., McDonough, W.F., Spicuzza, M.J., Valley, J.W. & Haggerty, S.E. (2002) Geochemistry of xenolithic eclogites from West Africa, part 2: origins of the high MgO eclogites, Geochimica et Cosmochimica Acta, 66, 24, 4325-4345. ISSN 0016-7037, DOI: 10.1016/S0016-7037(02)01004-9. http://www.sciencedirect.com/science/article/pii/S0016703702010049

[21] Koidu Holdings (2008) Koidu Kimberlite Project. http://www.koiduholdings.com

[22] Tompkins, L.A., Bailey, S.W. & Haggerty, S.E. (1984) Kimberlitic chlorites from Sierra Leone, West Africa; unusual chemistries and structural polytypes. American Mineralogist, 69(3-4), 237-249.

[23] Slowey, E. (2007) Independent Report on Diamond and Gold Projects in Sierra Leone, at the request of Avivit Minerals Company Ltd. (AMR). CSA Consulting International Ltd (CSA) Report No. CI 369.

[24] Avivit Minerals Company (2008) Gold, Platinum and Diamond Projects in Sierra Leone – Company Introduction. http://www.amrsl.com

[25] Hall, P. K. (1968) The diamond fields of Sierra Leone. Bull. Geol. Surv. Sierra Leone 5, 1, 133pp.

[26] Sutherland, D.G. (1982) The transport and sorting of diamonds by fluvial and marine processes. Econ. Geol., 77, 1613-1620.

[27] Stellar Diamonds Plc (2010) Annual Report & Accounts 2010 - A leading diamond producer in West Africa. http://www.stellar-diamonds.com/i/pdf/Annual Report/Stellar Diamonds Plc Annual Report 2010.pdf

[28] Sierra Leone Diamond Company Ltd. (2006) Annual Report 2006.

[29] Ikona, C.K. (2006) Cream Minerals: Technical Report on Alluvial Diamond Properties EPL 1/94 & EPL 5/94 Sierra Leone – for Cream Minerals Ltd. Pamicon Developments Ltd.

[30] http://www.slmineralresources.org/mining_sector/sl_mineral_sector_detaileddescription.pdf

[31] Cluff Gold plc (2010) 2009 annual report and accounts: London, United Kingdom, 60 p. http://www.cluffgold.com/DocumentDownload.axd?documentresourceid=145

[32] Arthur, J. & Bonson, C. (2010) Technical Review of the Baomahun Gold Exploration Project, Sierra Leone.
http://www.cluffgold.com/DocumentDownload.axd?documentresourceid=72

[33] SRK Consulting (2008) NI-43-101 Independent Mineral Resource Estimation of the Komahun Deposit, Sierra Leone – Report prepared for AXMIN Inc.
http://www.axmininc.com

[34] http://www.aureus-mining.com

[35] http://www.african-aura.com

[36] Anger G.; Raufuss W. & Weggen K. (1980) Zur Exploration der Lagerstaette Rotifunk, Sierra Leone /Westafrika. Exploration of the Rotifunk Deposit in Sierra Leone, West Africa. Erzmetall, Volume: 33, 4, 210.

[37] Titanium Resources Group Ltd. (2006) http://www.sierra-rutile.com/media/79190/30_January_2006_%20Acquisition%20_RotifunkMineralSands.pdf

[38] Titanium Resources Group Ltd. (2005) World's largest rutile (titanium dioxide) mine to restart. Sierra Leone production, Freetown, Sierra Leone: Titanium Resources Group Ltd., Press release, February 28, 2 p.

[39] Raufuss, W. (1973) Struktur, Schwermineralfuhrung, Genese und Bergbau der sedimentaeren Rutil Lagerstaetten in Sierra Leone: Geol. Jahrb., Reihe D, No. 5, 52 p.

[40] Sierra Leone Investment and Export Promotion Agency (2010) SLEITI Validation Report 2010 http://sleiti.org/pdf/validation_report.pdf

[41] Gambogi, J. (2010) Titanium mineral concentrates: U.S. Geological Survey Mineral Commodity Summaries 2010, p. 172-173.

[42] Kimberley Process Rough Diamond Statistics (2010) Annual global summary—2009 production, imports, exports, and KPC counts: Kimberley Process Rough Diamond Statistics,

July 8.
https://kimberleyprocessstatistics.org/static/pdfs/AnnualTables/2009GlobalSummary.pdf

[43] Macleod Dixon LLP (2010) Sierra Leone beyond Diamonds: Ambitious Reform to Unlock Opportunities for Investment in the Mining Sector. Presentation March 9, 2010. www.macleoddixon.com

[44] Sierra Leone Investment and Export Promotion Agency (2011) Be Part of the New Sierra Leone. http://www.sliepa.org/why-sierra-leone

[45] Avivit Minerals Company (2008) AMR Mineral Exploration Company. http://amrsl.com/uploaded/files/AMR%20%20Mineral%20Exploration%20company.ppt

[46] TRG (2006) TRG Completes Acquisition of the rights to the Rotifunk Mineral Sands Prospect in Sierra Leone. http://www.sierra-rutile.com/media/79190/30_January_2006_%20Acquisition%20_RotifunkMineralSands.pdf

6 Appendix

Tab. 6.1: Locations of the described deposits and exploration targets.

No.	Commodity	Company	Area	Locality	UTM Zone (E N)	Decimal Degree Lat / Lon	Degree° Min' Sec'' Lat / Lon
1	Diamonds	Koidu Holding	Yengema-Koidu	Pipe 1	29N 283006 / 954485	8.62981 / -10.97187	8° 37' 47" N / 10° 58' 18" W
2	Diamonds	Koidu Holding	Yengema-Koidu	Pipe 2	29N 283727 / 954848	8.63312 / -10.96534	8° 37' 59" N / 10° 57' 55" W
3	Diamonds	Koidu Holding	Tongo	4 dykes + 1 blow	29N 274299 / 908636	8.21494 / -11.04878	8° 12' 53" N / 11° 02' 55" W
4	Diamonds	Stellar Diamonds	Yengema-Koidu	Pol-K	29N 278000 / 952284	8.60967 / -11.01724	8° 36' 34" N / 11° 01' 02" W
5	Diamonds	Stellar Diamonds	Yengema-Koidu	Bardu	29N 275500 / 950000	8.58890 / -11.03984	8° 35' 20" N / 11° 02' 23" W
6	Diamonds	Stellar Diamonds	Tongo	dykes 1-4	29N 275951 / 911608	8.24188 / -11.03393	8° 14' 30" N / 11° 02' 02" W
7	Diamonds	AMR	Yengema-Koidu	Fiama North 1	29N 295000 / 960000	8.68020 / -10.86317	8° 40' 48" N / 10° 51' 47" W
8	Diamonds	AMR	Yengema-Koidu	Fiama North 2	29N 295500 / 954500	8.63050 / -10.85838	8° 37' 49" N / 10° 51' 30" W
9	Diamonds	AMR	Tefaya	Tefaya	29N 256696 / 963023	8.70567 / -11.21129	8° 42' 20" N / 11° 12' 40" W
10	Diamonds	AMR	Katumpeh	Katumpeh	28N 805000 / 1045000	9.44261 / -12.22268	9° 26' 33" N / 12° 13' 21" W
11	Diamonds	African Minerals	Tefaya	Konama Mine	29N 256627 / 961733	8.69401 / -11.21185	8° 41' 38" N / 11° 12' 42" W
12	Diamonds	Cream + Casierra	Hima	Hima	29N 180383 / 858600	7.75768 / -11.89747	7° 45' 27" N / 11° 53' 50" W
13	Gold	Cluff Gold	Baomahun	Baomahun	29N 206000 / 932500	8.42693 / -11.66982	8° 25' 36" N / 11° 40' 11" W
14	Gold	AXMIN	Komahun	Komahun	29N 260000 / 950000	8.58813 / -11.18061	8° 35' 17" N / 11° 10' 50" W
15	Gold	Aureus	Sonfon	Sonfon	29N 225388 / 1032676	9.33333 / -11.50000	9° 20' 00" N / 11° 30' 00" W
16	Gold	AMR	Laminaya	Laminaya	28N 826000 / 1040000	9.39589 / -12.03201	9° 23' 45" N / 12° 01' 55" W
17	Gold	AMR	Tafaya	Tefaya	29N 256696 / 963023	8.70567 / -11.21129	8° 42' 20" N / 11° 12' 40" W
18	Gold	AMR	Kate	Kate	28N 803000 / 1058000	9.56020 / -12.23994	9° 33' 36" N / 12° 14' 23" W
19	Gold	AMR	Gori Hills	Gori Hills	29N 295500 / 946000	8.55366 / -10.85801	8° 33' 13" N / 10° 51' 28" W
20	Rutile	Sierra Rutile	ML016/72	Taninahun Boka Deposit	28N 771138 / 905548	8.18472 / -12.53917	8° 11' 05" N / 12° 32' 21" W
21	Rutile	Sierra Rutile	ML015/72	Benduma Deposit	28N 776222 / 880835	7.96111 / -12.49444	7° 57' 40" N / 12° 29' 40" W
22	Rutile	Sierra Rutile	ML015/73	Kampatia Deposit	28N 777080 / 885697	8.00500 / -12.48639	8° 00' 18" N / 12° 29' 11" W
23	Rutile	Sierra Rutile	ML015/74	Dodo Deposit	28N 774949 / 883533	7.98556 / -12.50583	7° 59' 08" N / 12° 30' 21" W
24	Rutile	Sierra Rutile	ML015/75	Kibi Deposit	28N 773354 / 883646	7.98667 / -12.52028	7° 59' 12" N / 12° 31' 13" W
25	Rutile	Sierra Rutile	ML015/76	Komende Deposit	28N 779271 / 883098	7.98139 / -12.46667	7° 58' 53" N / 12° 28' 00" W
26	Rutile	Sierra Rutile	ML015/77	Gbap Deposit	28N 772278 / 889387	8.03861 / -12.52972	8° 02' 19" N / 12° 31' 47" W
27	Rutile	Sierra Rutile	ML014/72	Nyandehun Deposit	28N 789977 / 881382	7.96528 / -12.36972	7° 57' 55" N / 12° 22' 11" W

Tab. 6.1 cont.: Locations of the described deposits and exploration targets.

No.	Commodity	Company	Area	Locality	UTM Zone (E N)	Decimal Degree Lat / Lon	Degree° Min' Sec'' Lat / Lon
28	Rutile	Sierra Rutile	ML013/72	Jagebhun Deposit	28N 797704 / 880755	7.95917 / -12.29972	7° 57' 33" N / 12° 17' 59" W
29	Rutile	Sierra Rutile	ML012/72	Gambia Deposit	28N 791418 / 871676	7.87750 / -12.35722	7° 52' 39" N / 12° 21' 26" W
30	Rutile	Sierra Rutile	ML011/72	Bamba/Beleu Deposit	28N 799990 / 863922	7.80694 / -12.28000	7° 48' 25" N / 12° 16' 48" W
31	Rutile	Sierra Rutile	ML011/72	Mogbewmo Deposit	28N 801602 / 861105	7.78139 / -12.26556	7° 46' 53" N / 12° 15' 56" W
32	Rutile	Sierra Rutile	ML011/72	Mokula Deposit	28N 795593 / 861066	7.78139 / -12.32000	7° 46' 53" N / 12° 19' 12" W
33	Rutile	Sierra Rutile	ML011/72	Ndendmoia Deposit	28N 802875 / 858746	7.76000 / -12.25417	7° 45' 36" N / 12° 15' 15" W
34	Rutile	Sierra Rutile	ML011/72	Pejebu Deposit	28N 803723 / 855585	7.73139 / -12.24667	7° 43' 53" N / 12° 14' 48" W
35	Rutile	Sierra Rutile	ML011/72	Lanti Deposit	28N 798533 / 847097	7.65500 / -12.29417	7° 39' 18" N / 12° 17' 39" W
36	Rutile	Sierra Rutile	ML011/72	Gbeni Deposit	28N 795453 / 849322	7.67528 / -12.32194	7° 40' 31" N / 12° 19' 19" W
37	Rutile	Sierra Rutile	ML011/72	Gangama Deposit	28N 791427 / 855507	7.73139 / -12.35806	7° 43' 53" N / 12° 21' 29" W
38	Rutile	Sierra Rutile	ML011/72	Taninahun Deposit	28N 791156 / 859686	7.76917 / -12.36028	7° 46' 09" N / 12° 21' 37" W
39	Rutile	Sierra Rutile	ML017/72	Mosavi	28N 807895 / 846142	7.64583 / -12.20944	7° 38' 45" N / 12° 12' 34" W
40	Rutile	Sierra Rutile	Rotifunk	Rotifunk	28N 755816 / 909951	8.22534 / -12.67792	8° 13' 31" N / 12° 40' 40" W

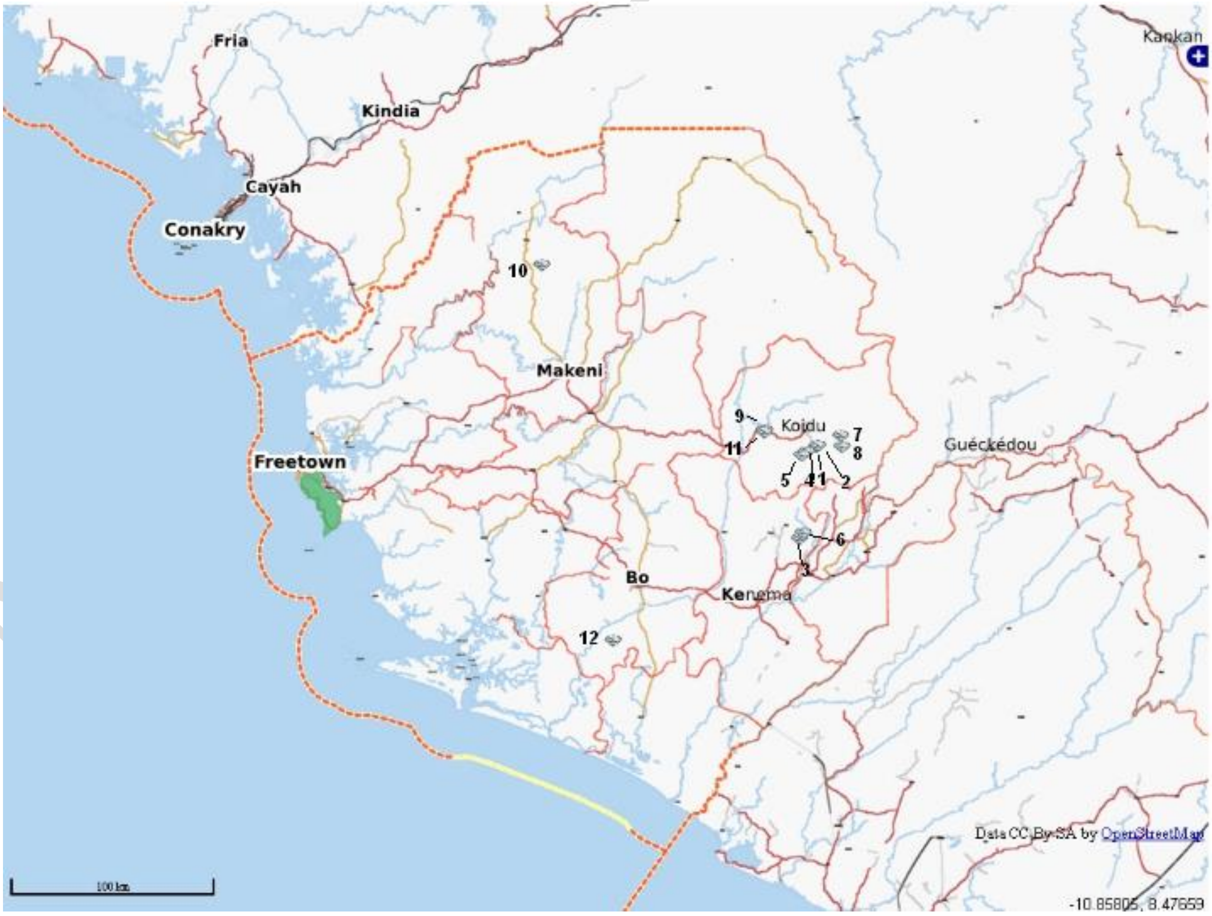

Fig. 6.1: Locations of diamond deposits and exploration targets. Refer to Tab. 6.1 for numbers.

Fig. 6.2: Locations of gold deposits and exploration targets. Refer to Tab. 6.1 for numbers.

Fig. 6.3: Locations of rutile deposits and exploration targets. Refer to Tab. 6.1 for numbers.

7 Imprint

J.M.W. Geo-Consulting
Dr. J.M. Warnsloh
http://jmw-geo.com
info@jmw-geo.com

This report was created in spring 2011. All text and figure sources are cited within the text and listed in the references chapter. Where web publications were used, the links (URL) got listed in the references, too. Due to rapid changes in the World Wide Web, I am not responsible for the availability of the listed links and their content. – Website structures may have been changed, businesses bought by other companies or online services simply laid down. Further, I am NOT responsible for the validity of the used documents cited in this report.