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Regolith Mapping and Gold Geochemical Anomalies in the Siguiri Gold Mine of AngloGold Ashanti, Guinea, West Africa

By

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A dissertation submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
(Exploration Geology)

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DECLARATION

I, Bah Boubacar, declare this dissertation to be my own work. It is submitted in fulfillment of the Degree of Master of Science at the University of Rhodes. It has not been submitted before for any degree or examination in any other University or tertiary institution.

Signature of the candidate: ……………………………………….

Date: ………………………………………………………………

ABSTRACT

Gold exploration in the laterite terrains of the Siguiri basin (Guinea-West Africa) is discussed in this thesis. It seeks to propose and develop effective and reliable geochemical exploration techniques applied in such laterite terrains. The study is also intended to investigate and provide some geological clues as to why, in some target areas, the reconnaissance test drilling across the geochemical anomalies couldn't intersect economic gold mineralisation. Targets were generated based on soil geochemical results, some of which were drilled without delivering economic discoveries even on areas with strong and consistent geochemical signatures. To find the failure and define the appropriate methods to be used is the core of the thesis.

More importantly, the geological observation is aimed at sourcing and establishing the nature and validity of geochemical anomalies within the license area and their relationship with the underlying lithologies and structural networks. The geological field work conducted during this study is mostly based on regolith and surface geological mapping.

The thick laterite cover, deep weathering, bedrock geology, gold geochemistry (the gold geochemical anomalous results are defined according to historical data before 2007), soil formations and variations in climate conditions are emphasized to illustrate the importance of mineral element mobility and dispersion in the weathering profiles. The knowledge and experience in regolith geochemistry and regolith mapping provide the advantage to exploration geologists.

The depletion of ore resources and reserves in Siguiri and the continuous decline of the gold price in comparison to the complexity of exploring for gold are demanding more scientific-related thoughts and techniques to be integrated in the available geological, geochemical and geophysical information so as to reduce costs. The integration of good exploration strategy and technique may result in the possibility of making viable discoveries in this highly competitive geological environment where the mineral resources become depleted every day.

ACKNOWLEDGEMENTS

I take this opportunity firstly to thank God for giving me life and health. I express my gratitude to everyone who supported me throughout the course of this Msc program. I am thankful for their aspiring guidance, invaluably constructive criticism and friendly advice during the project work. I am sincerely grateful to them for sharing their truthful and illuminating views on a number of issues related to the project.

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My thanks go through to Hatari Mjinja and Eddie Connell, for taking their time to review my thesis. I also extend my recognition to the entire Siguiri Gold Mine Exploration team, in particular to the 2013 target field assessment team, for their hard work.

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This thesis is dedicated to the memory of the late Peter Winkler and Robb Bonell.

Contents

List of Figures

List of Tables

Chapter 1 : Introduction

1.1 Background

Guinea covers an area of 245,857 km^2 with an estimated population of 9,932,000 residents as per the 2007 population statistics and is rich in various mineral commodities such as gold, diamonds, bauxite and iron ores, which remain largely under- explored and exploited.

The country has a number of industrial-scale gold mines, namely, Siguiri (AngloGold Ashanti), Lefa (Norgold/Severstal) and Kéniéro (SEMAFO), as well as other small projects operating in the area known as 3K (Avocet Mining) and Balandougouba in Mandiana and Shawn, Tinko and FK in Siguiri area (Bullman mineral Inc.); Kassidy Gold Corp in Kourousa area; and Doko Mining in Siguiri area.

Guinea also has several large bauxite deposits at Sangaredi, Kindia and Fria and abundant iron ore at Simandou and Nimba. This requires the country with a small work force to develop its mining industry skills. With increasing international expenditures on exploration funds, a healthy mining sector in Guinea is substantially created. Although there is a shortage of engineers, geologists, technicians and trained equipment operators, a large unskilled labour force is available.

The northeastern region of Guinea and the central-northern region of Mali are situated in the center of an ancient gold-mining district that is believed to have been a major gold producer since the 3rd century, at the time of the Mandingo Empire. The first records of modern mining activity in Guinea are dated back to 1903, whereas the first mechanized mining operation is recorded in 1909, when a stretch of the Tinkisso River was dredged for alluvial gold. Throughout the 20th century various exploration and mining operations were undertaken by Australian, French and Russian companies in close proximity to the present Siguiri Mining Complex (Paranhos, 2008). Ashanti Goldfields acquired Golden Shamrock and its 85% interest and named the mine Ashanti Goldfields de Guinée (SAG) in 1998. In 2004 AngloGold acquired the mine and merged with Ashanti Gold Fields Ltd to form AngloGold Ashanti. The resource at Siguiri is estimated to be 107.6 Mt at average gold grade of 0.85 g/t, including 60.4 Mt of proven and probable reserves averaging 1.21 g/t of gold.

Siguiri gold mine is a multiple open-pit oxide operation, in which AngloGold Ashanti holds an 85% share with the remaining interest held by the Government of Guinea.
AngloGold Ashanti continues to actively drive the creation of value by growing its mineral resources and reserves. The drive is based on the well-defined and active Brownfields and Greenfield exploration program, innovation in geological modelling and mine planning as well as continuous optimization of its asset portfolio.

Siguiri mine covers a concession area of 1,500 km^2 in the relatively remote district of Siguiri, about 850 km northeast of the country's capital Conakry and around 270 km to Bamako (capital of Mali). The area has significant potential for gold mineralization, and it has been a long record of traditional artisanal mining.
There is no known record of commercial production from artisanal mining at the Siguiri district. The production has been limited to artisanal gold mining as evidenced by the presence of fairly widespread, but shallow diggings and using metal detectors as an aid to finding small gold nuggets in the upper portion of the lateritic duricrust. The gold recovery by artisanal miners is normally by crushing, washing using a calabash or a small conveyor belt.

Local economic activity is closely connected to the gold mining. Conventional mining is undertaken by contractors in multiple open-pits using conventional excavator digging techniques. A Carbon in Leach (CIP) processing plant treats about **32,000t** on a daily basis at Siguiri gold mine.

The need for new exploration target generation to sustain the life of Siguiri Gold Mine (LoSGM) is triggered by the continuous depletion of the ore reserves in the oxidized zones, annual increases in production costs and the intensified local community demands.

1.2 Location of the study area

Siguiri Gold mine is located approximately 800 km NNE of the capital Conakry and 25 km NW of Siguiri town (district centre). The nearest international departure is Bamako the capital city of Mali located about 270 km ENE of Siguiri. The Mine is centred at latitude 11° 32.9' N and longitude 9° 14.4' W. The infrastructure on a broad scale is typically poor although the main secondary roads within and around the mine to Siguiri are easily accessible as they are continually being rehabilitated by the mine. Siguiri can also be accessed via a small airfield and as well as a well maintained paved road that connects Siguiri to Bamako in the north and Kankan-Kouroussa to the south (**Figure 1**).

Figure 1: Location of the Siguiri Gold Mine (red star) in relation to Conakry on the coast and Bamako across the border in Mali (source: [www.nationsonline.com,](www.nationsonline.com) June 2014).

1.3 Surface topography

The topography of the region is variable between 300 m to 850 m above mean sea level. The vegetation is typically savannah and comprises sand banks along the Niger and other rivers, clay-rich, duricrust, ferruginous soils, and gravel, which is subdivided into (Guinea Geology):

- Lithosols developed over duricrust plateaus, buttes, and dismantled duricrust slopes;
- Lithosols developed over areas of outcrop or sub-outcrop ridges, buttes, inselbergs, slopes and valley bottoms;

- Non-indurated ferruginous and over different types of substrates; or indurated ferruginous soils developing over duricrust plateaus;
- Hydromorphic soils over alluvial sediments

1.4 Climate

The climate is tropical with distinct wet and dry seasons. An average rainfall of about 1300 mm per year is largely restricted to the wet season between June and October, with very little rain falling outside the wet season. The climate is warm in winter and hot in summer with an average temperature of 27 °C, and extremes of between 10 °C and 45 °C. Malaria is a problem during the wet season although SAG does implement a malaria prevention campaign. The dry season is typically hot and dry with the Harmattan dust-laden wind blowing off from the Sahara Desert to the north-east (Guinea Geology).

1.5 Vegetation and regolith formation

The landscape is dominated by gently undulating savannah with scattered dolerite capped hills which can rise up to 400 m above the local surroundings. Towards the north an escarpment of sandstone and conglomerates extends across the area in an ENE-WSW direction. These rocks are younger than the Birimian and define the northern limit of the Siguiri Basin. The northeast flowing Niger River is the dominant river in the area, with the town of Siguiri being located on the banks of the river. The Tinkisso River flows along the southern boundary of the property and the Koba River flows through the mining area.

The landscape at Siguiri is a combination of multiple surfaces and slopes; however the African bauxite surface is not present within the area mapped. The ferruginous duricrust at Siguiri are superimposed on an already truncated weathering profile. As such, the uppermost parts of a classical lateritic profile are missing and regolith profiles are commonly developed (Skwarnecki, 2013).

Figure 2: Typical landscape of Siguiri area showing trees with grass, high elevation and slope with boulders of cuirasse and the saprolite along the drill cut line (this study, 2014).

1.6 Mineral Economics

Guinea occupies the 21st position in the world country rank, with **18,083.00 kg Au** and in 2008 was the fifth largest producer in Africa of diamonds and gold commodities accounting for 3.2 per cent of the diamonds and 4.35 per cent of the gold output, respectively. Diamonds and gold are mined and exported on a large scale. Diamond output, is mostly artisanal production from alluvial deposits sourced from kimberlites (**http://spilpunt.blogspot.com/2007/04/guinea.html**).

Among its other mining resources the bauxite ore constitutes the major source of foreign exchange revenues, accounting for almost 40% of the bauxite world trade with average annual exports of approximately 14 million tonnes per year (Ministry of Mines and Geology, 2005c). All bauxite deposits occur in the western and central parts of the country and were formed through the alteration of dolerites, crystalline schists and nepheline syenites from Neoproterozoic and Paleozoic strata during the peneplanation and laterization of this region. The average thickness of the ore varies from 3 to 9 m (Ministry of Mines and Geology, 2005c). Access to the deposits is easy and mining is carried out in open pits. The ore is transported via railway to a port on the coast.

Diamonds of gemstone quality occur in southern Guinea. They are originated from Mesozoic kimberlite dykes and pipes, which are controlled by deep seated fracture systems. Diamonds occur as alluvial and elluvial deposits. The artisanal diamond mining is mostly done in relict heavy mineral concentrations in near-surface fractures in Ordovician quartzites in the Kindia area of western Guinea (Ministry of Mines and Geology, 2005b). Guinea was a participant in the Kimberley Process (Wright, 2004).

Major iron ore (more than 4-billion tonnes of high-grade iron) deposits, which are composed of Banded Iron Formations (BIF) of Archean rocks, occur at Mt Nimba and Mt Simandou in the south east of Guinea. The Simandou iron ore project is "the largest integrated iron ore mine and infrastructure project ever developed in Africa, with the potential to transform the Guinean economy and transport infrastructure and Kalia iron ore project is expected to produce 7 million tonnes per year with production planned to start in 2015

(**http://spilpunt.blogspot.com/2007/04/guinea.html**).

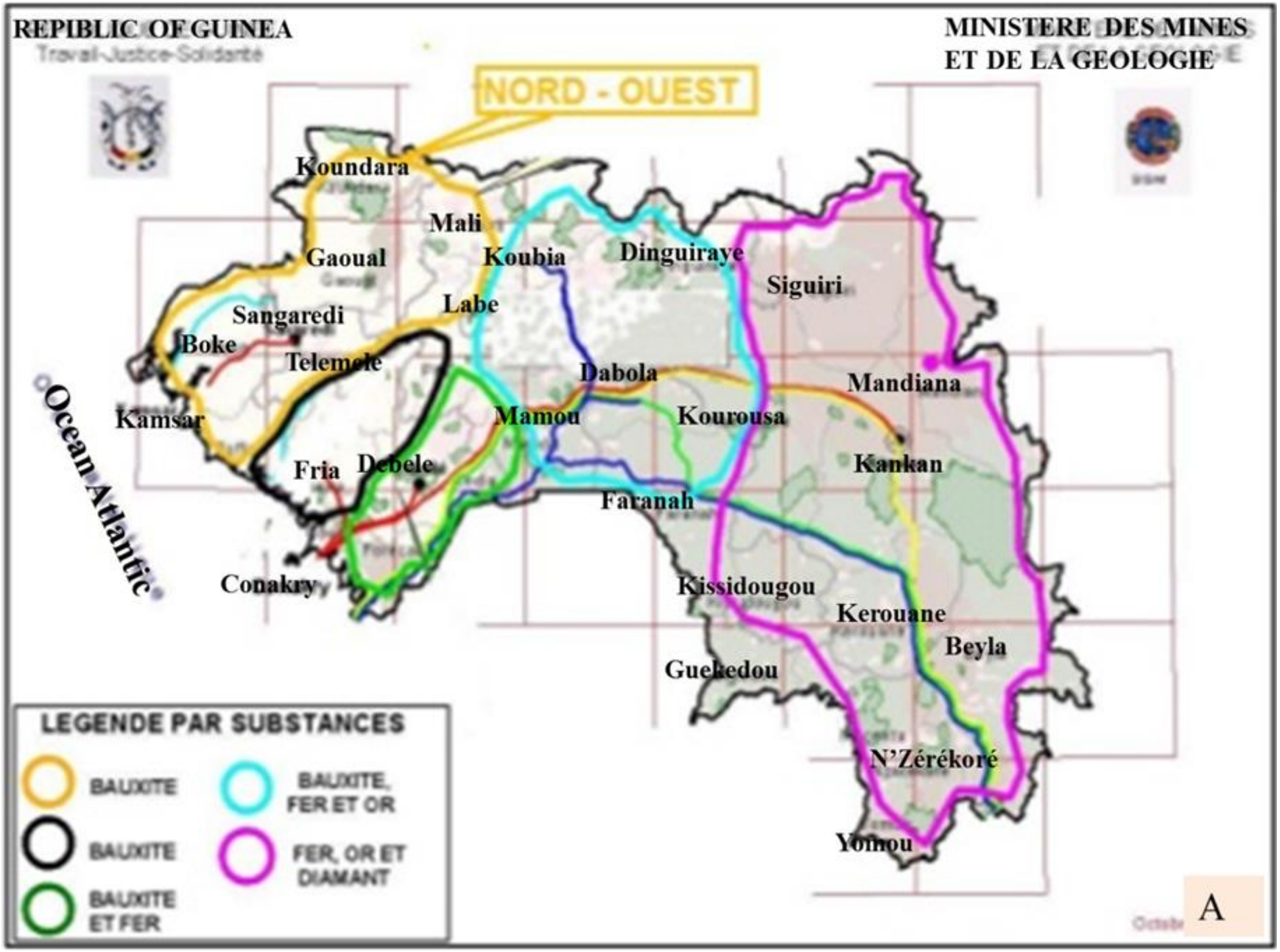
The Mt Kakoulina operation is a copper-nickel-cobalt-PGM polymetallic deposit. Undetermined quantities of uranium occur in the north of the country along the border region with Mali and also in the southern region Ferawa around kissidougou
(**http://spilpunt.blogspot.com/2007/04/guinea.html**).

Ilmenite, rutile, zircon, tourmaline, etc. are associated with sands from shorelines and large watercourse beds, such as the Niger, Nandian, and the Bofon rivers. Economic deposits are known in Cape Varga, Boffa and Benty, but as yet they are not exploited.

Hydrocarbon exploration within Guinea began in 1968, while the existence of offshore oil resources has since then been confirmed, but no production as yet in takes place (**http://spilpunt.blogspot.com/2007/04/guinea.html**).

Gold is found primarily in shear-zone hosted Paleoproterozoic greenstone belts and associated placers in the northeast of Guinea. But most economic deposits are those, which were formed through enrichment during lateralisation process. Artisanal mining of alluvial and laterite gold is locally widespread.

Gold production which increased by 23 per cent in 2008, was largely attributed to expanded capacity at the Lefa Mine and the Lefa corridor has a reported gold resource of 150 tonnes of gold.


REPIBLIC OF GUINEA
Travail-Justice-Solidarité
MINISTERE DES MINES
ET DE LA GEOLOGIE
NORD - OUEST
Koundara
Mali
Gaoual
Koubia
Dinguiraye
Siguiri
Sangaredi
Labe
Boke
Telemele
Dabola
Mandiana
Ocean Atlantic
Kamsar
Mamou
Kourousa
Fria
Debele
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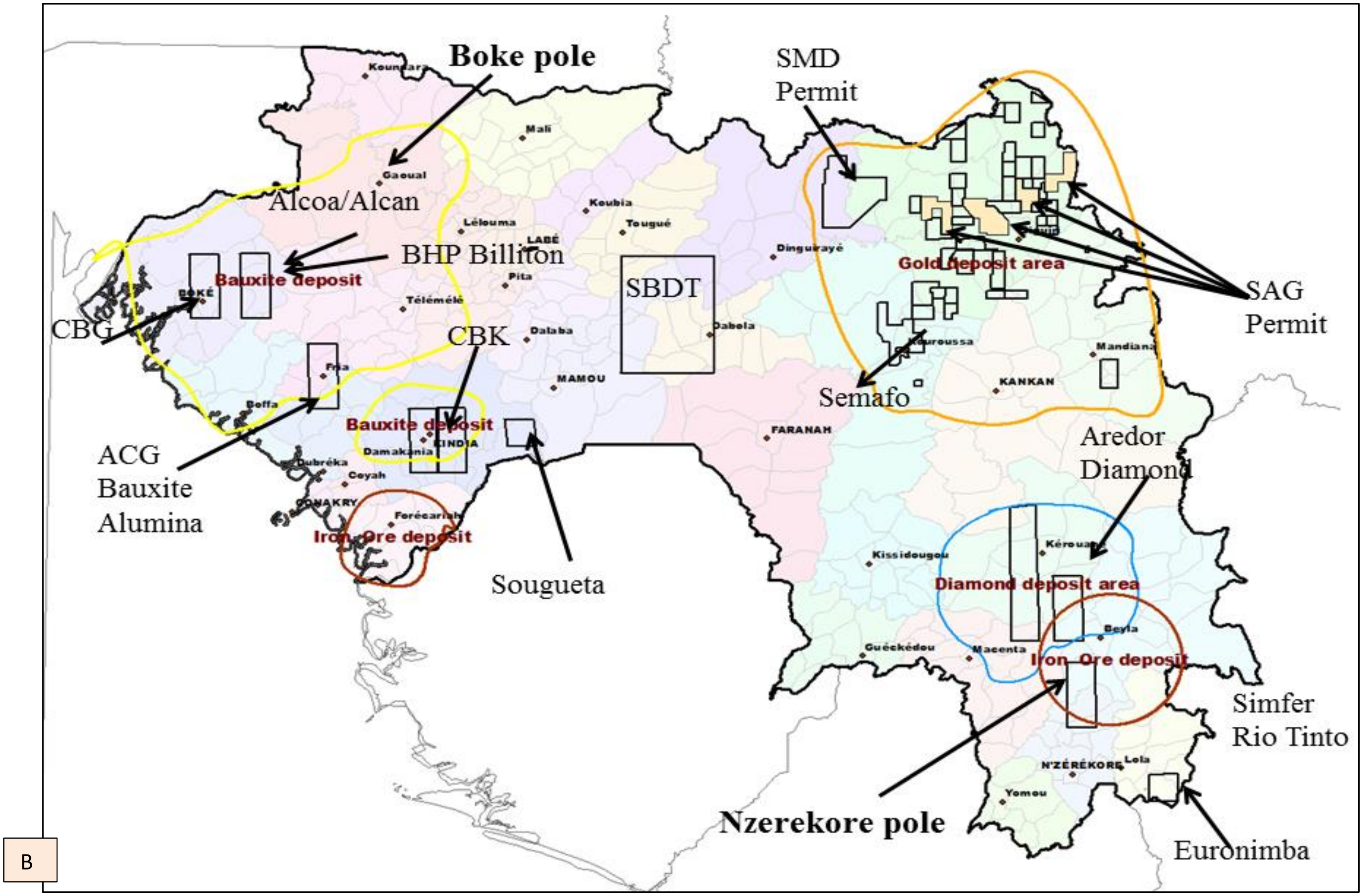

Figure 3: Guinea Maps, respectively on Page 8 and Page 9: **a**. shows the distribution and extent of the mineral potential throughout Guinea (Scandal Geologic) and **b**. Resource Corridors throughout the country (this study, 2014) and (http://spilpunt.blogspot.com/2007/04/guinea.html)**.** **SMD**= Société Minière de Dinguiraye, **SAG**= Société Ashanti de Guinée, **SEMAFO**= Société d'Exploitation Minière d'Afrique de l'Ouest-Guinée (SEMAFO-Guinée).

1.7 Objectives

In 2008 a number of reconnaissance targets were generated in Block 1 at Siguiri (for details, see Chapter 3 **Figure 10**), some of them were drilled without delivering economic discoveries even on areas with strong and consistent geochemical signatures. This study is undertaken to investigate and find out the geological observations as for the reason why the surface mineralisation could reflect any bedrock mineralisation regardless of presence of favorable host rocks and structural setting of some of these target areas.

A review of the (geochemical, geophysical and drilling) exploration data and regolith mapping within the license areas were undertaken as an approach towards resolving this problem. In addition the following aspects are considered equally important:

- Carry out intensive reviews of the target generation exercises conducted at Siguiri and re-rank all the geochemical and geophysical targets generated up to date.
- Apply and integrate the geological information gained from the known deposits around Siguiri to review the geochemical and geophysical signatures so as to refine the newly emerging targets.
- Conduct detailed regolith and surface geological mapping and provide completed and meaningful geological interpretations.
- Make use of geophysical datasets (gravity, magnetics and EMs, radiometric imageries) to integrate with drilling, mapping and geochemical data to establish a clear understanding of the controls of gold mineralisation within the area.
- Study geomorphological mapping and landform context (DTM, Satellite and Landsat imageries) to interpret and differentiate regolith regimes.
- Make use of pathfinder elements distribution (more likely arsenic) in the regolith and their correlation with gold.
- From the exercises conducted above conclusion can be drawn to answer the questions and solve the problems.

Chapter 2 : Methodology

2.1 Regolith mapping

A detailed field exercise was carried out in November and December 2013, together with Marian Skwarnecki, Senior Manager of AngloGold Ashanti, and expert on Geochemistry for the Continental Africa Region. The aim is to investigate and find out if the materials in the deep cover of laterite are in situ or transported. Arial photo imagery together with topography contours and a digital image of the Siguiri Block1 as depicted below area served as the base map for regolith mapping. A total of 1466 localities were visited to best describe terrain within the Block1.

The initial approach was followed by general mapping using a Garmin GPS, notebook and taking readings of the GPS coordinate and described the material type where the reading took places along vehicle tracks and at higher elevations. The field work aimed to collect maximum information over Block1 and to be used in conjunction with the soil geochemistry data so as to produce a regolith map. Sampling of the different types of cuirasses where submitted for assays and photographs of cut diamond drill core were taken to illustrate these features.

Another field regolith mapping was designed to carry out from January to May 2014, and its aim is to conduct a field assessment of each target, by detailed target mapping, to establish the nature and validity of geochemical anomalies and/or confirm the geological interpretation of structural trends and lithologies.

Two teams are deployed in the field, and each team conducted mapping a specific target before moving to the next. A field mapping sheet was designed and implemented to standardise the mapping procedure and ensure that the data is gathered uniformly across all targets.

The sheet's primary purpose is to distinguish between transported and in-situ residual cover. This distinction is considered the main factor influencing the validity of geochemical anomalies. Areas mapped as duricrust, colluvial gravel and or alluvial/colluvial/aeolian soils revers to a transported sample medium while saprolitic soil/clay/gravel refers to a more residual saprolitic source. However, cognisance is taken wherever duricrust with angular, >3cm diameter, saprolitic or bedrock clasts are observed.

Further attention was placed on locating rock/saprolite outcrops while gathering as much structural data as possible. Outcrop is limited in the area and where possible, structural readings and quartz-vein data are recorded using a Brunton-type structural compass. Readings of planar elements are given as dip direction and dip angle, and all readings are given with respect to true north, corrected for a westerly declination of 5.43 degrees (area magnetic declination year 2013).

Artisanal mining activities are also documented as a possible indication of in-situ or transported gold occurrences. Activities either focus on shallow pits, worked by metal detector, extracting gold from transported cover or as local miners' tunnel, up to 4 m deep, into the sub-surface where gold occurs in quartz veins associated with in-situ saprolite. Miners have also been observed targeting the interface between duricrust and saprolite, indicating a possible enrichment process occurring along the un-conformal contact.

A grid pattern of 200*100 m is used during the target regolith mapping program and the procedure consists of working alone the line and taking reading at every 100 m and reporting to the purpose primary sheet. All GPS coordinates are downloading using map source or DNR Garmin software transfer to Microsoft Excel program. All information are entered in excel and import to ESRI ArcMap™ (version 10.2). A polygon shapefile are created from Arc catalog to draw the different lithotype for each target.

All GPS readings are recorded with reference to the datum WGS 84 and 29N and maps are drawn using ESRI ArcMap™ (version 10.2).

2.2 Surface geochemical soil sampling and sample analysis

Surface geochemical soil sampling in Block1 was designed and carried out between 2007 and 2010. The soil sampling programme initiated to facilitate target generation within the Block1 was carried out along two grids: one grid oriented North-South (for example as used at Balato, Niono, Seguelen, and Silakoro) and the other along an East-West grid (Kourouda SE and Kourouda SW). The North-South grid covers the northern part of the block whereas the East-West grid covers the southern portion of the block 1. The orientations of the two grids were based on the orientation of the major structural trends that exist within the sampling area.

A 200m x 50m spaced grid is used to take the soil samples. The coordinates of each point is in UTM. Two teams consisting of one geologist, one technician, four samplers and one driver is used to carry out the work.

2.2.1 Sampling procedure

The soil pit is dug by hand using a sharp-edged pick-axe to a recommended depth between 30cm to 50cm. However, in areas with thick transported cover, the pits are deepened in excess of 50cm to ensure that the black organic soils have been penetrated and are avoided.

A 2 to 3 kg sample is collected from each sample location and packed in the plastic bags labeled with Zebra-printed ticket numbers. Each number includes five digits and contains the original name of the project area (e.g. 1BL00001 for Block1).

All field data is captured in the database (Datashed in the past and Fusion century System from March 2013) before the samples are submitted to the laboratory (SGS). The Aqua Regia method of analysis, with low detection limits, is used to analyse the soil samples.

The photographs in the Figure below depict the sequence of steps followed during the soil sampling procedures. The coordinate of the point location is entered into the GPS and located on the ground. A strip of flag is tied on a branch to indicate the location of the sampling point. A hole is dug to a depth of 30-50cm or until the appearance of the soil changes to orange in the case of laterite or shades of grey or white for saprolite. The recommended weight of a sample is 2.5-3kg and is placed into a small bag. The UTM coordinates of the sampling point are recorded and must be the same as that in the planned grid. This is recorded together with the sample number & marked on the label and the description of the collected materials.

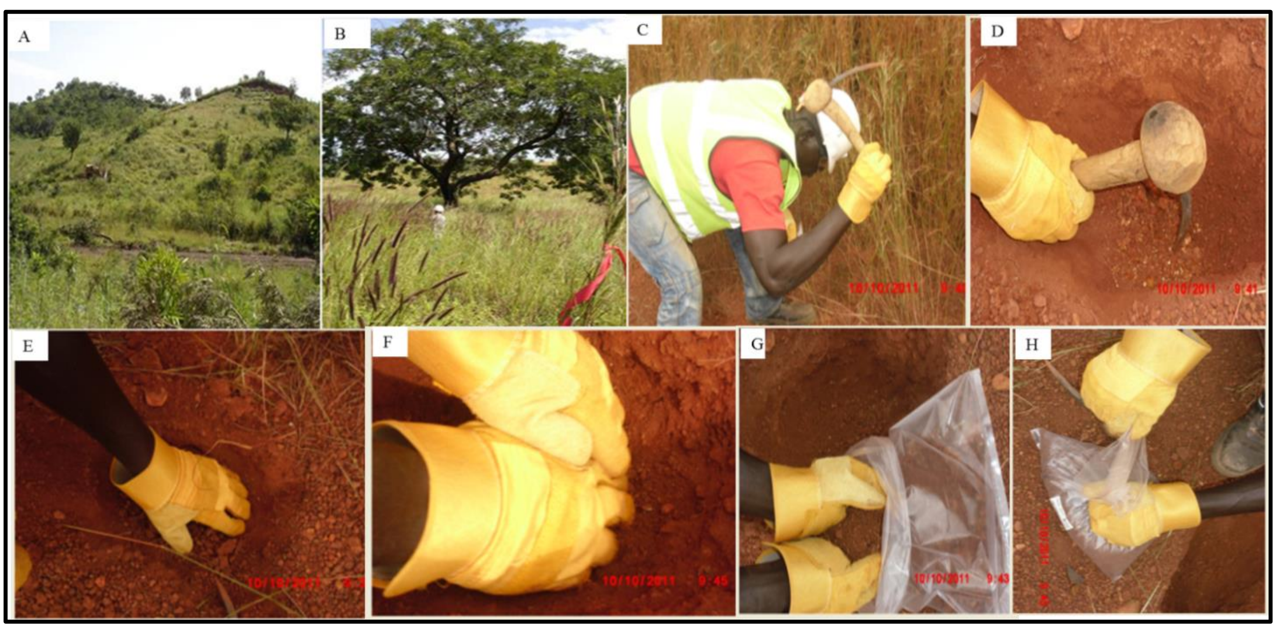

Figure 4: Photographs depicting the procedures for undertaking a soil sampling programme (Soil sampling procedure, 2011). A. The coordinate of the point location is entered into the GPS and located on the ground, B. A strip of flag is tied on a branch to indicate the location of the sampling point. C. A 30-50cm deep hole is dug until the appearance of the soil changes - orange in the case of laterite, D- changing the appearance of the soil, E. Removing top soil until the color change, F. Collecting samples materiel, G. putting materiel into plastic bag with estimated recommended weight (2.5-3kg), H. sample collection completed and tied the small plastic bag the recommended weight of a sample is 2.5-3kg and is placed into a small bag.

The UTM coordinates of the sampling point are recorded and must be the same as that in the planned grid. This is recorded together with the sample number & marked on the label and the description of the collected materials.

2.2.2 Data collection and preparation

The figure below shows the sampling sheet used to standardize data collection.

The following information is required Geologist name, sample id, XYZ coordinates of the sampling point, a short description recognizing the type of materials collected (soil, gravel, and duricrust), the constituents, the topographical setting of the site, vegetation and the summary of the sample describing the regolith units and the possible underlying geology of the area.

The log sheet information is entered into a digital database, into which the assay data will be added captured once submitted by the lab. It is recommended that the progress of the digital capture of the logs keep up with the sampling progress. The database must contain a data field recording who logged the samples. This is used to check for subjectivity bias or other discrepancies by the person who records the logging. All data is available for extracting from database in csv or dbf format and used for further interpretation.

MINERAL RESOURCES MANAGEMENT DEPARTMENT

ANGLOGOLD ASHANTI

BRONFIELDS EXPLORATION

SURFACE GEOCHEM SAMPLING SHEET

PROSPECT:.. DATE .... /............./ 20 GEOLOGIST:..

SampleID	Sample Type	Coordinates utm_E	Coordinates utm_N	Elevation	Weight	Lithcode	Outcrop	Description

Figure 5: Log sheet template used for data collection in field (this study, 2014).

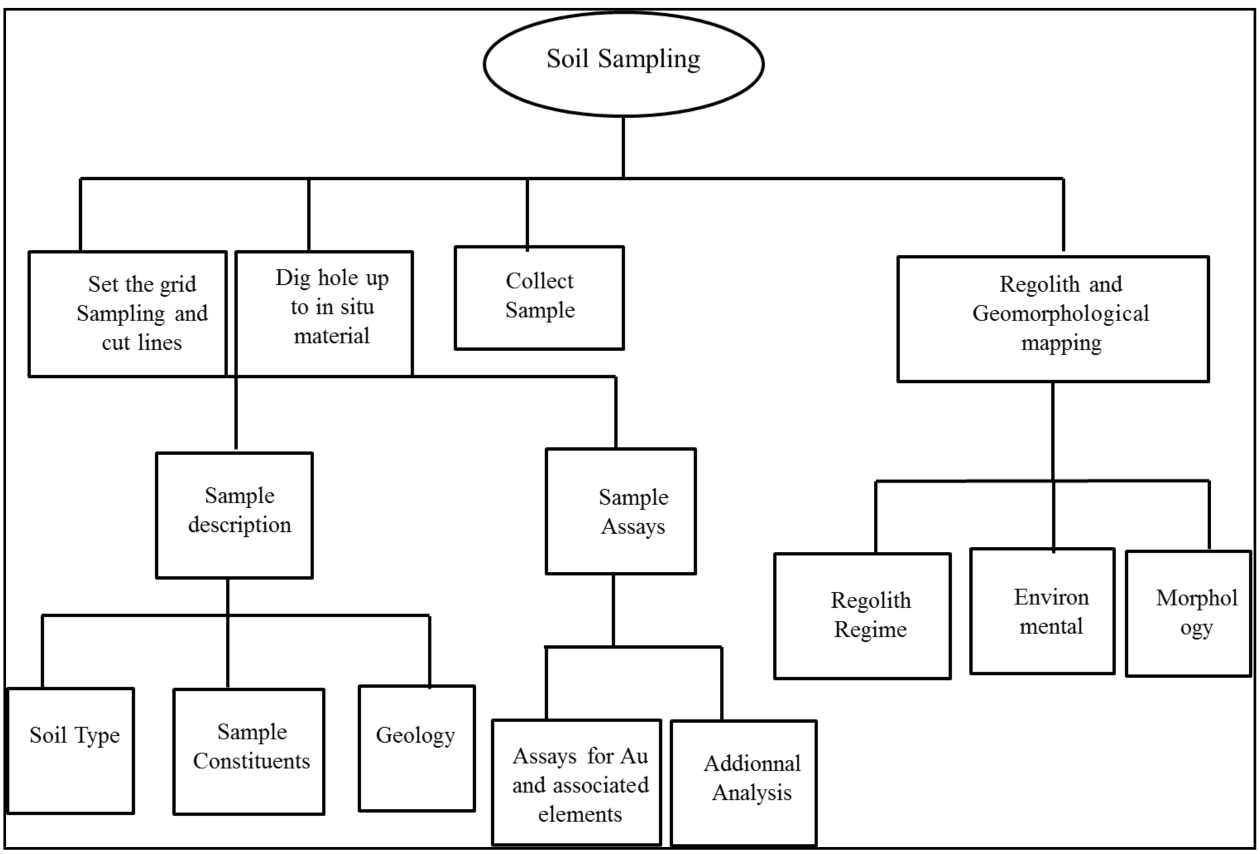

Figure 6: Diagram depicting the soil sampling protocol (this study, 2014).

2.2.3 Topographical observations

Using the information logged it is possible to:

i. Achieve a meaningful interpretation of the soil results.
ii. Validate sample positions when plotted over the Landform and Regolith map.
iii. Audit sample crew reliability.

It important to provide brief descriptions and explanations to supplement what has been recorded in the log sheet.

The dominant "soil" or surface regolith present is described. This information can also support evidence for other observations such as landscape position or regolith regime. The loam color is important - the pinkish loams are most often associated with eroding acrolith (edge; top; highest point), whereas pale loams can have higher colluvial / aeolian component.

It is vital to know what has been submitted for assay, especially the proportion of quartz to iron. Ideally, the percentage should be by mass, but if this is impractical, estimates should be by percentage abundance. A diagram that show various percentage abundances are recommended to record more information:

I. Slope direction, the down slope direction will support the dispersion analysis and validate the sample position plotted over the Landform and Regolith map.

II. Landscape position which is principally used to validate where samples plot over the Landform and Regolith map. Some discrepancies between the map and the field recorded position can be expected as it is not always possible in the field to know exactly where you are in the landscape, due to high grass and views being obscured.

III. Recording the regolith regime in the field can provide a more accurate means than the Landform and Regolith map (where this has been compiled following interpretation of remote sensing data) for subdividing the soil results into populations with similar regolith characteristics.

IV. Vegetation needs to differentiate between ground that has been cultivated and soils turned over, or 'natural' vegetation. Recording vegetation also assists with sample/logging validation by cross checking with accurately referenced recent remote sensing data such as Landsat TM, Aster and Orthophotos images. The difference between woodland and open woodland savannah is somewhat subjective and relates to tree density. The bulk of the wooded terrain would be termed 'open woodland savannah' while 'woodland' refers to denser stands of trees usually found on floodplains and along river courses. Grasslands are most often present on cuirasse plateaus.

2.2.4 Analytical procedure

The soil samples are taken to SGS Koron laboratory at Siguiri for gold and arsenic analyses. The rock chips and gravels are crushed before splitting, which is done by means of a riffle splitter, and then pulverized to -75 meshes. A 200 to 250 g pulverized sample is scooped into an envelope, out of which a final 50 g aliquot split is weighed for Aqua Regia digest. Gold analysis is performed at a lower detection limit of 2 ppb whereas the arsenic analysis is performed at a lower detection limit of 20 ppm.

2.3 Quality Assurance and Quality Control

Quality Assurance and Quality Control (QA/QC) protocols are followed where suitable standards and blanks are inserted at each twentieth sample interval. The insertion alternates between a blank and a standard. Similarly field duplicates are taken and inserted after every twentieth sample. Thus a total of two QA/QC samples are inserted at every twenty samples. On taking the field duplicate, a second pit is dug adjacent to the original sample pit and to the same depth and or dig one pit and split the sample. This QA/QC insertion is done prior to the samples being submitted to the SGS laboratory.

2.4 Data processing and interpretation

Microsoft Access and Excel programs are used for data management, QA/QC, the plotting graphs of blank, standard and duplicate samples, statistical analyses, descriptive tools for statistic, and histogram and log probability plot for data interpretation.

ESRI ArcMap™ (version 10.2) software is used to monitor all data and measure the values with different methods. These consist of importing data extract from the fusion database, and geo-reference with WGS84 UTM 29N (area setting).

A Geostatistical technique is used to create surfaces incorporating the statistical properties of the measured data. This technique is used not only to produce prediction surfaces but also error or uncertainty surfaces, giving an indication of how good the predictions are.

Understanding output surface types explains the types of prediction maps, which the geostatistical technique is used to create each map with and without a standard error.

Many methods used in geostatistics are all in the Kriging family. Ordinary, Simple, Universal, Probability, Indicator, and Disjunctive Kriging, along with their counterparts in Co-Kriging, are available in Geostatistical Analyst. Not only do these Kriging methods create prediction and error surfaces, they can also produce probability and quartile output maps depending on your needs.

2.4.1 Kriging and Co-Kriging

A Kriging method is an interpolator that can be exact or smoothed depending on the measurement error model. It is very flexible and allows one to investigate graphs of spatial auto- and cross-correlation. Kriging uses statistical models that allow a variety of output surfaces including predictions, prediction standard errors, probability and quartile. The flexibility of Kriging can require a lot of decision-making. Kriging assumes that the data come from a stationary stochastic process, and some methods assume normally-distributed data.

2.4.2 Inverse Distance Weighting (IDW)

Inverse Distance Weighting (IDW) is a quick deterministic interpolator that is exact. There are very few decisions to make regarding model parameters. It can be a good way to take a first look at an interpolated surface. However, there is no assessment of prediction errors, and IDW can produce "bull’s eyes" around data locations. There are no assumptions required for the data.

The inverse distance weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locational dependent variable.

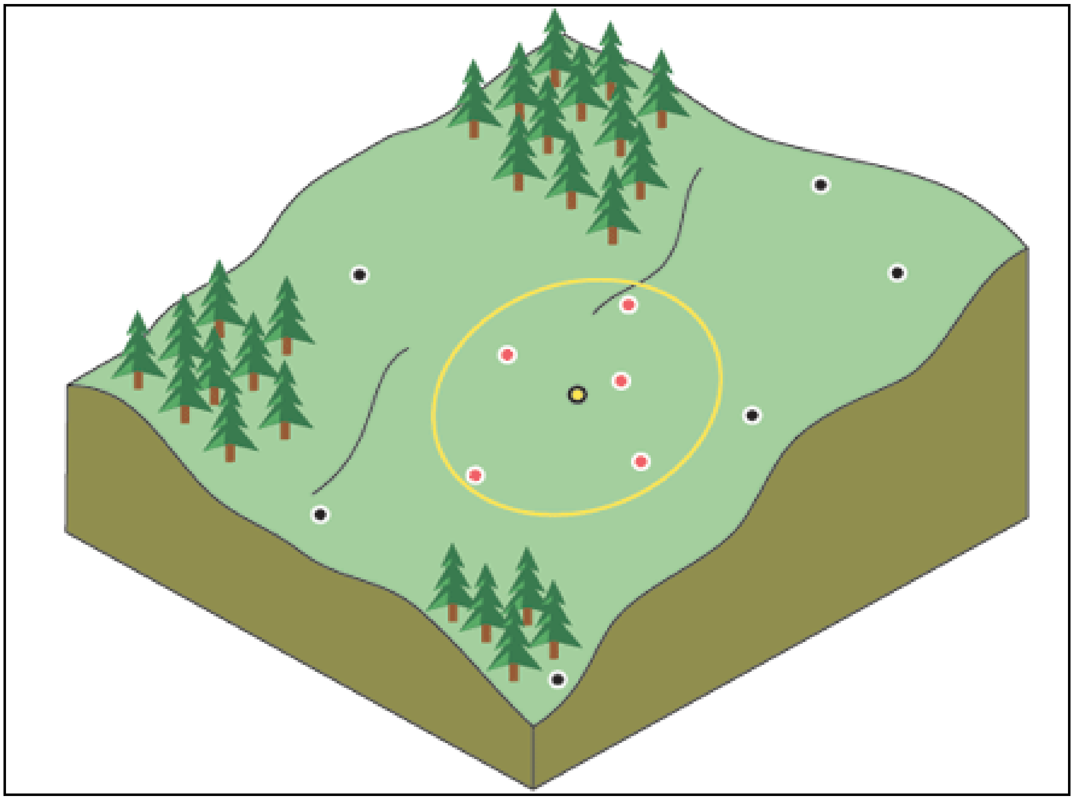

Figure 7: The method assumes that the variable being mapped decreases in influence with distance from its sampled location (*Source ESRI ARCGIS 10.2 version, 2014*).

In Geostatistical Analyst an Inverse Distance Weighted (IDW) methods will be used in soil geochemistry and drill-hole data to measure the values surrounding the prediction location; to predict a value for any unsampled location, an assumption is made that things closer to one another are more alike than those that are farther apart.

- The predicted value is limited to the range of the values used to interpolate. Because IDW is a weighted distance average, the average cannot be greater than the highest or less than the lowest input. Therefore, it cannot create ridges or valleys if these extremes have not already been sampled.
- IDW can produce "bull’s eyes" around data locations.
- There are no assumptions required for the input data.
- This method is well suitable for use with very large input datasets.

Chapter 3 : Geological Setting and Regional Geology

3.1 Tectonic setting

The 2.2–2.0 Ga West Africa Craton is dominated by the greywacke sequences of the Birimian "greenstone" belts, which like many other Precambrian belts are argued to have been generated by either collisional tectonics or mantle plume activity.

3.1.1 Tectonic Units

The tectonics of the region consists of two main groups of Precambrian rocks that are part of the West African Craton (BRGM, 1988).

- The oldest are Archean rocks commonly known as Kenema-Man Archean domain composed of gneisses, migmatites, granitoids and schists.
- The second group consists of rocks of early Proterozoic ages formed during the Leonien and the Liberian orogenesis. The youngest are supracrustal rocks which occur overlying the Archean basement and are characterized by clastic-chemical sedimentary and volcanic sequence related to the early Proterozoic. These are referred to as the **Birimian Supergroup.**

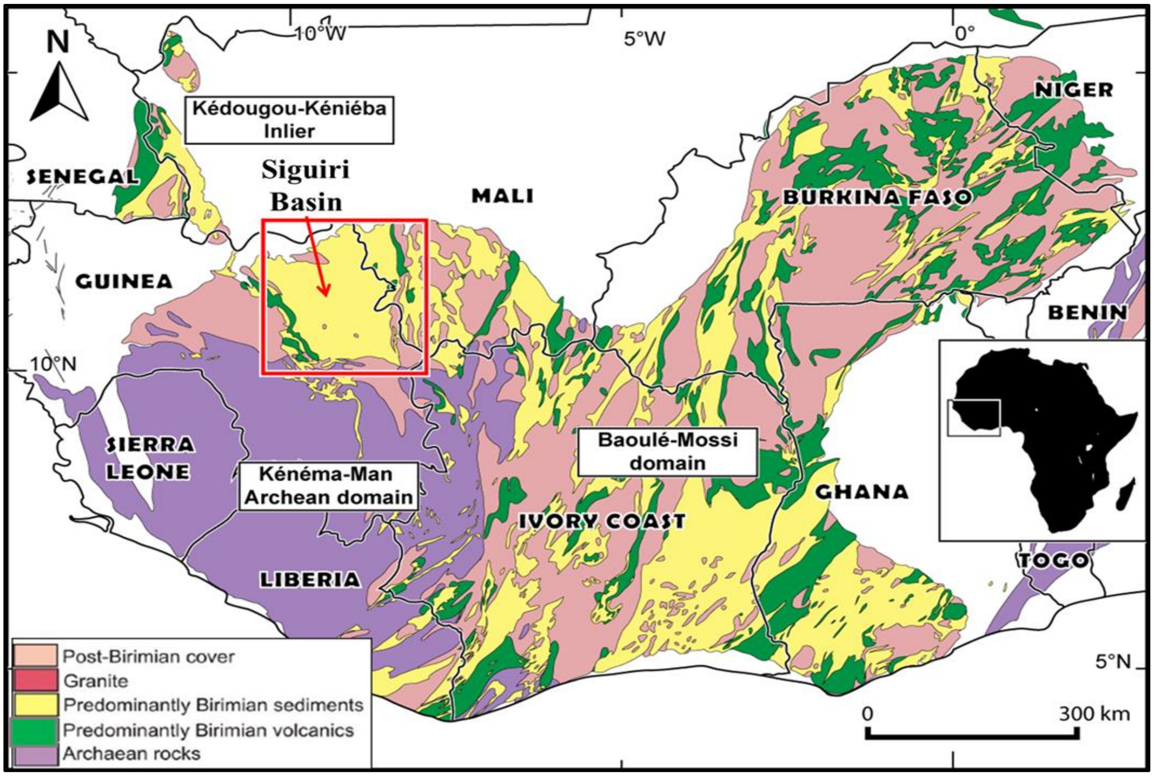

Figure 8: Regional geological map of West Africa showing the Main Cratons surrounded by narrow greenstone belts units (BRGM, 1988).

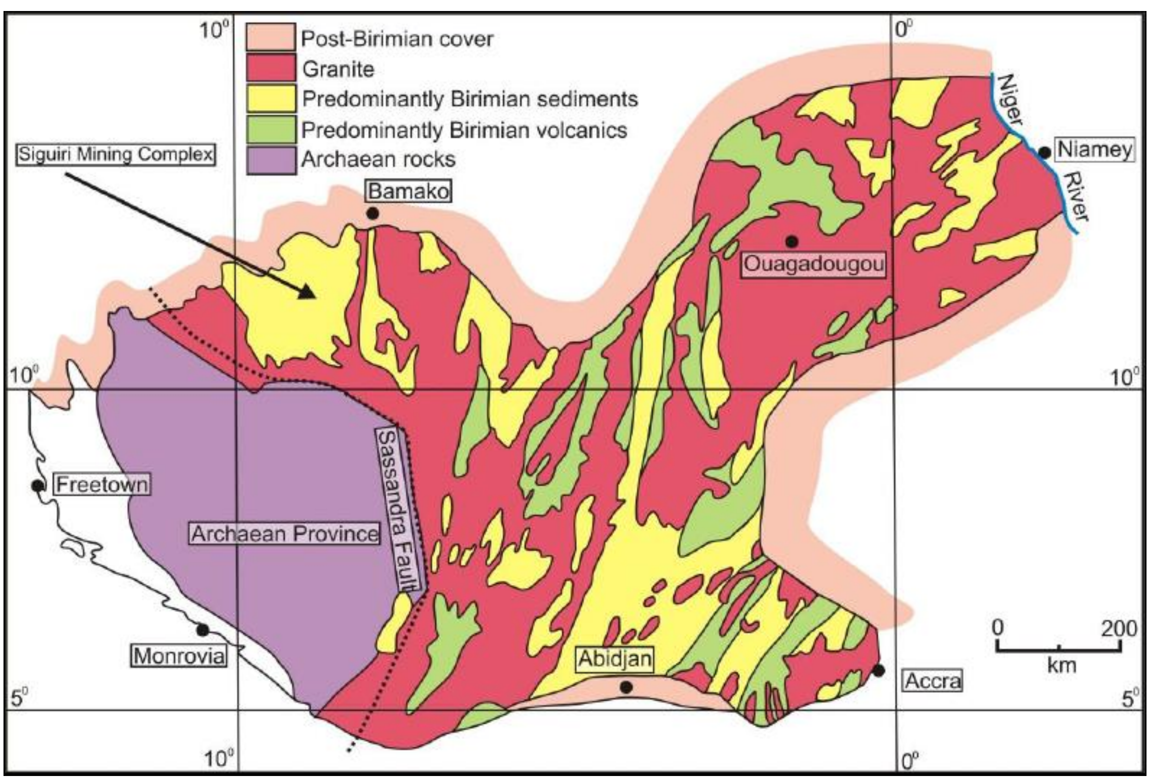

Figure 9: Geological sketch map of the Archean-Paleoproterozoic Man-Leo Shield showing Archean basement gneisses and linear to arcuate volcano-sedimentary belts intruded by voluminous granitoids (*Feybesse and Milési, 1994).*

3.1.2 Provincial Stratigraphy

The Achaean units in Côte d´Ivoire are bounded in the east by the prominent Sassandra fault, a large N-S regional fault, which separates the Achaean units from younger Paleoproterozoic metasediments and metavolcanics units further to the east. The northern boundary is marked by an extensive, shallow dipping fault marking a zone where the same Paleoproterozoic units of Guinea and northern Côte d´Ivoire were thrust southwards on to the older cratonic block (Deckart et al., 1997 and Emmanuel et al., 2001).

The Birimian Supergroup was deposited and deformed during the Erbunean Orogeny (2,100-2,000 Ma) and comprise volcano-sedimentary sequences overlying uncomfortably the Archean basement. They are preserved as mostly linear volcanic belts and adjoining sedimentary basins. The volcanic sequences are composed of basic lavas surrounded by rhyolite domes capped by black schists. The broad sedimentary basins are filled with a thick upward coarsening sequence of argillites, siltstones and talus type turbidite capped by carbonate beds and felsic volcanics.

Basic to acidic intrusive batholiths are associated with late Eburnean Orogeny and occurred over vast areas of the Shield. A later generation of dykes and plutons are co-genitic with the volcanic belts or related to intense mylonite zones and with deep reaching fault systems found in the domain. The abundant gold mineralization found in the Birimian Supergroup is most likely related to late tectonic plutonism and related hydrothermal events that have mobilized gold in favorable tectonic traps, along fractures and fault zones (Deckart et al., 1997 and Emmanuel et al., 2001).

Recent geological investigation carried out mainly by universities and sponsored by the World Bank in cooperation with French Geological Survey (BRGM) has revealed a vast plutonic belt that rims the margin of the Archean Ke´ne´ma–Man Craton and is made up of a variety of granitic rocks (granodiorite, biotite granite, monzogranite, two-mica granite), granodiorite, with common clinopyroxene, being the most abundant. The occurrence of per aluminous two-mica granites at the northern extension of the plutonic belt in the Siguiri Basin may suggest that the convergence here was associated with the local melting of metasedimentary rocks in the deeper part of the basin related to regional convergence by major WNW–ESE sinistral movements along the northwestern margin of the Archean block (**Figure 8**).

The stratigraphic column of the Archean and Proterozoic geology of West Africa is provided in Table 1.

Table 1: Stratigraphic column of the Archean and Proterozoic geology of West Africa (modified from Deckart et al., 1997 and Emmanuel et al., 2001)

Period	Age	Event	Product	Metallogeny
Neo-Proterozoic	620 – 520 Ma	Pan African Orogeny	Plataformal sediments , granitoid and gabbro intrusion	Gold, copper, bismuth, nickel
Neo-Proterozoic	1,400– 1,300 Ma	-	Sediments	-
Meso-Proterozoic	2,100-2,000 Ma	Eburnean Orogeny	Deformation, metamorphism, regional alteration and granitoid intrusion	Gold, Cu
Paleo-Proterozoic	2,100-2,175 Ma	Birimian Supergroup	Intermediate to basic volcanics, volcaniclastcs, greywake, graphite schists, dolomites	Gold, Fe, Cu, Mn
Archaean	> 3.6 – 2.5 Ga	Reguibat and Leo-Man cratons and Mount Nimba Formation	High grade metamorphic terrenes and granite-greenstone belts	Gold, Iron

3.1.3 Structure

Structurally, the Siguiri Basin abuts against the Archean Man Craton to the west and during the Eburnian a number of easterly verging thrust fronts were developed. These structures have been interpreted using magnetic susceptibility data as outcrop data in the basin are rare. Siguiri is located on one of these structures. A number of NE-SW trending intrusions are also present in the area, although they are younger Mesozoic dolerites and grano-diorites (Feybesse et al., 1994 and Ledru et al., 1994).

In Ivory Coast and Ghana the structural history is as follows (Feybesse et al., 1994 and Ledru et al., 1994):

D1 (N) NW – (S) SW shortening: "Burkinian" orogeny associated with high grade metamorphism at lower crustal levels and the development of east-west to east- north-east to west- south-west trending fabrics, 2.13-2.14 Ga.

D2 (W) NW – (E) SE shortening and development of fold thrust belt at 2.1Ga; Low to medium grade metamorphism, with foliation trending at 030˚. D1 fabrics show anti-clockwise rotation; Start of "Eburnian".

D3 W(NW) – E(SE) shortening resulting in dextral transgression results in steeply plunging folds of D2 fabrics, the development of north-south trending open-close F3 folds and conjugate fault/shear zones with dextral faults with 035˚ -080˚ strikes and sinistral faults with 320˚ -360˚ strikes; End of "Eburnian" at 2.09Ga.

D4 +N(NE)-S(SW) shortening; widespread low strain with shallowly inclined foliation, north-north-east and south- south-west verging thin skinned thrusting and small scale east-west striking kinks due to folding.

Most Au is associated with the "Eburnian" D2 and D3 deformation. A similar history could be expected in the Siguiri Basin, although it is possible that the two areas were separated by a large "Himalayan" –type range (Watts, 2010).

3.1.4 Siguiri Basin within the Birimian Supergroup

The Siguiri basin is underlain by the **Birimian Supergroup.** The term "**Birimian**" was established by Kitson in 1919 and 1928 (Emmanuel et al., 2001) who defined the Birimian System in the Gold Coast of Ghana to describe the deformed and metamorphosed clastic sedimentary and volcanic rocks exposed in the Birimy River valley of southern Ghana. The rocks are the most important Paleoproterozoic units in West Africa that have proven to host economic gold deposits within extensive sedimentary and volcanic units across the region (Tahon, 1997).

The Birimian System consists of volcanic-epiclastic and sedimentary basins, as well as granitoids that mark a major juvenile crust-forming event culminated in the ca. 2.1 Ga Eburnian orogeny. The rocks are between 2.25 and 2.05 Ga old. The late Eburnean mesothermal Au mineralisation is responsible for the bulk of Birimian mineralisation and the large arsenopyrite-bearing deposits occur at or along major shear zones largely propagated along lithological contacts（Feybesse et al., 1994).

The compressional deformation during the Eburnean Orogeny resulted in the Birimian Series over-thrusting the Man Shield and the intrusion of granitoids within the neo-Proterozoic rocks. This collisional episode resulted in the development of dominantly greenschist facies metamorphism and a regional northeast to northwest trending deformation zones, considered to be fundamental to the development of gold mineralisation in the Birimian Series (Feybesse et al., 1994) similar to what has been interpreted at the Siguiri Gold Deposits. A number of NE-SW trending younger Mesozoic dolerites and grano-diorites intrusions are also present in the area (**Figure 10**).

3.2 Regional Geology

The Siguiri Basin is poorly exposed and overlain by saprolite and laterite covers. The deep level of weathering profile (>210 m in areas) blankets most of the lithologies and structures, although a number of geophysical techniques have been implemented to increase the geological knowledge of the area. Most of the structural elements within the Siguiri belt have common features, which are compatible with a single, extended and progressive phase of regional deformation involving substantial NW-SE compression, resulting in early stage N-S sinistral faults of regional extent and later stage dextral faults orientated approximately NE-SW and with a considerable amount of thrusting with a south-east vergence associated with Eburnean orogenic cycle at about 2200 – 2000 Ma (Feybesse et al., 1994 and Ledru et al., 1994),

The basin is dominated by turbidite sequences comprised of greywacke, mudstone, shale, siltstone, schist, quartzite, limestone and pyroclastic material, together with intercalated volcanic belts comprising mostly of mafic to intermediate extrusive rocks, together with pyroclastic flows. A number of granitoids have been emplaced during the Eburnian (**Figure 10**).

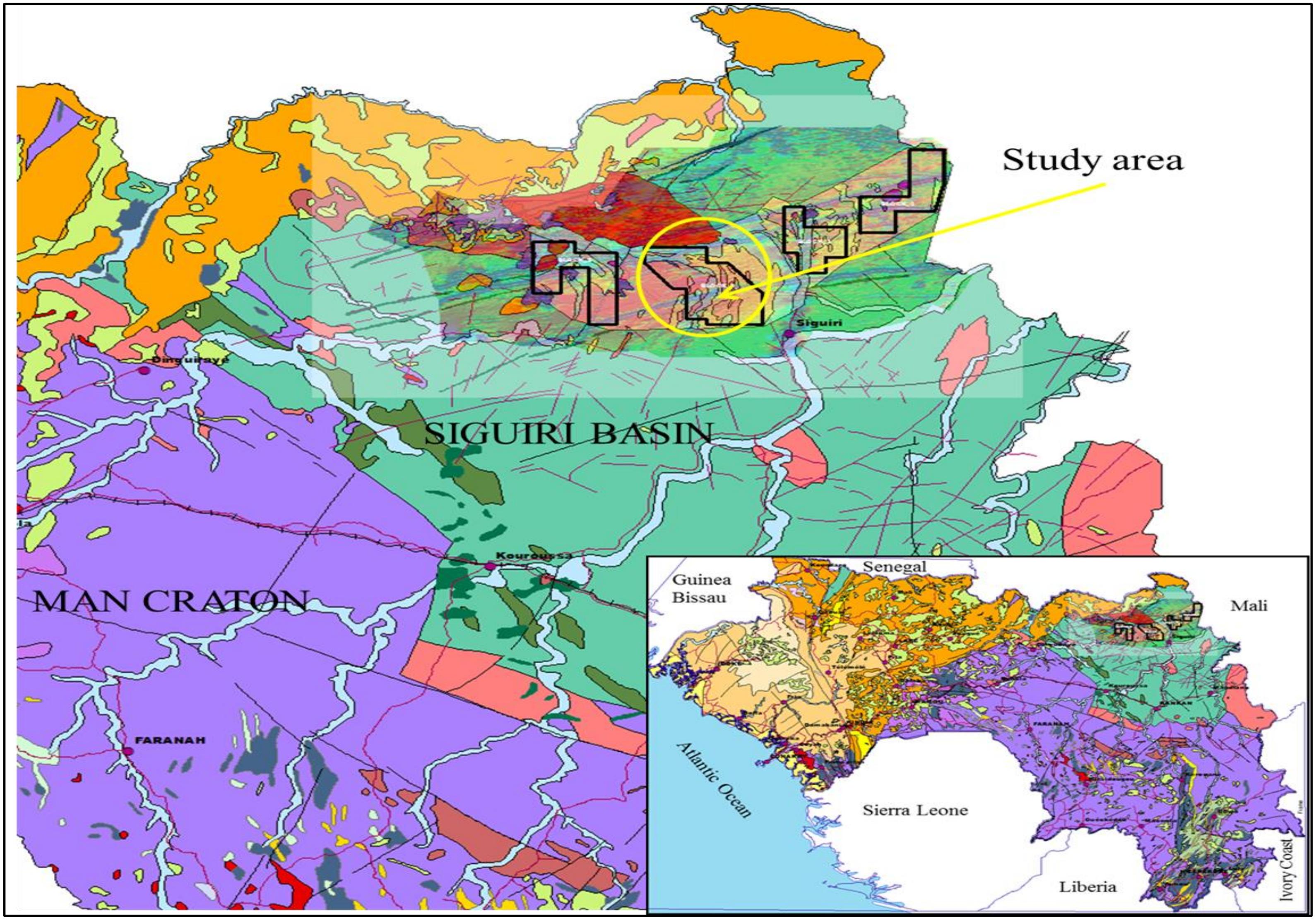

Figure 10: The Siguiri basin lies within the Birimian Supergroup (BRGM 1998), modified Guinea Geology Atlas shapefile using ArcGis 10.2 software. The study area is highlighted in yellow (this study, 2014).

Chapter 4 : Local Geology

The Siguiri Gold Mine occurs within 200,000 sq. km, Birimian-aged Siguiri Basin which is situated in the northeast of Guinea. The basin is underlain by Lower Proterozoic rocks of the Birimian meta-sedimentary and volcano-sedimentary formations (**Figure 10**). The sediments consist of well-bedded turbiditic sequences of the greenschist facies with siltstones present as the dominant lithology. Sandstones, greywackes and minor conglomerates, with some brecciated and possibly volcanic members are present, but the later members are of lower abundance compared to the siltstones.

On a regional scale the siltstone rocks are dominant towards east, while coarser-grained rocks are more prevalent towards the west of the license areas (e.g. Foulata- Saraya prospects). Some graphitic schist units have been identified in the drill core particularly in the Sintroko, Kami, Bidini and Seguelen areas. Younger intrusive diabase and dolerite dykes of Jurassic age have ENE-WNW orientation and are considered to be related to an opening of the Atlantic Ocean (Watts, 2010).

4.1 Lithology

Within the areas mined in Block1, the lithology is dominated primarily by siltstones and greywacke/sandstones, with minor amounts of black shale units and the occasional breccia present. Three major electromagnetic zones can be identified and each is thought to be possibly associated with different lithologies (**Figure 11**).

- The eastern zone, locally called the **B**alato **F**ormation has a very different electromagnetic signature to the other two units. The **B**alato **F**ormation is the oldest stratigraphy of the three (3) named formations in the region (Leburn, 2013). The lithology is composed of fine grained units of turbidite shales, black carbonaceous shales, ironstones and siltstones. Generally, there are no economically mineralized zones found in this formation, except at Sintroko where major structures were identified interpreted from the electromagnetic image were identified (**Figure 11**).

- The central zone, the **F**atoya **F**ormation, is well known as virtually all mining is restricted to this unit. The unit consists of interbedded siltstones and greywacke/sandstones, with minor black shales and represents a turbidite unit, often containing well developed and complete Bouma sequences. The **F**atoya **F**ormation represents a turbidite sequence dominated by greywackes but with minor portions of the lithology comprising of sandstones, siltstones and minor quantities of black shales. The altered nature of these rocks results in exact lithological descriptions difficult. Theron and Coetzee (2010) and Herron (1988) identified the main lithologies as continuum from feldspathic greywackes, siltstones to shales, with other lithologies including albitite, magnetite ironstones and pyritic carbonaceous shales (black shales) and carbonate-sericite schists. It is clear from drilling that the magnetite ironstones do not represent a true lithology, but rather a different alteration product as they cut across beddings. The Bouma sequences are often observed, both in mined exposures and in drill cores but rarely all the five Bouma units seen. A repetitive of 20-30 cm Bouma sequences can be observed in Kami pit.

- The western zone, known as the **K**intinian **F**ormation, is also well documented from drilling and consists of a monotonous series of fine-grained green to purple siltstones, shales and schists. The Kintinian shales are easily distinguished from other shales in the open pit exposures due to their greenish to purple tinge, extreme thickness, and veining and sulphide contents. Occasional intercalated breccias are present in places (**Figure 11**).

Approximately 15 km to the north-west of the current operations outcropping rocks occur and are composed of amphibolite facies meta-limestones, volcaniclastic meta-sandstones and quartzite. These rocks occur in a northeast vergence, semi-recumbent, anticlinorium that may be underlain by an early thrust fault that separates the lower grade facies in the east from the higher grade facies in the west (Holcombe, 2007).

The main difference between **F**atoya and **B**alato **F**ormation is the presence of thick shale units (thicker greater than 5 meters), which do not appear to occur as commonly as in the other parts of the Formations as compared to those found at Sintroko. It is possible that the higher shale content within the **B**alato **F**ormation gives rise to the EM image showing having a largely uneven and lumpy appearance.

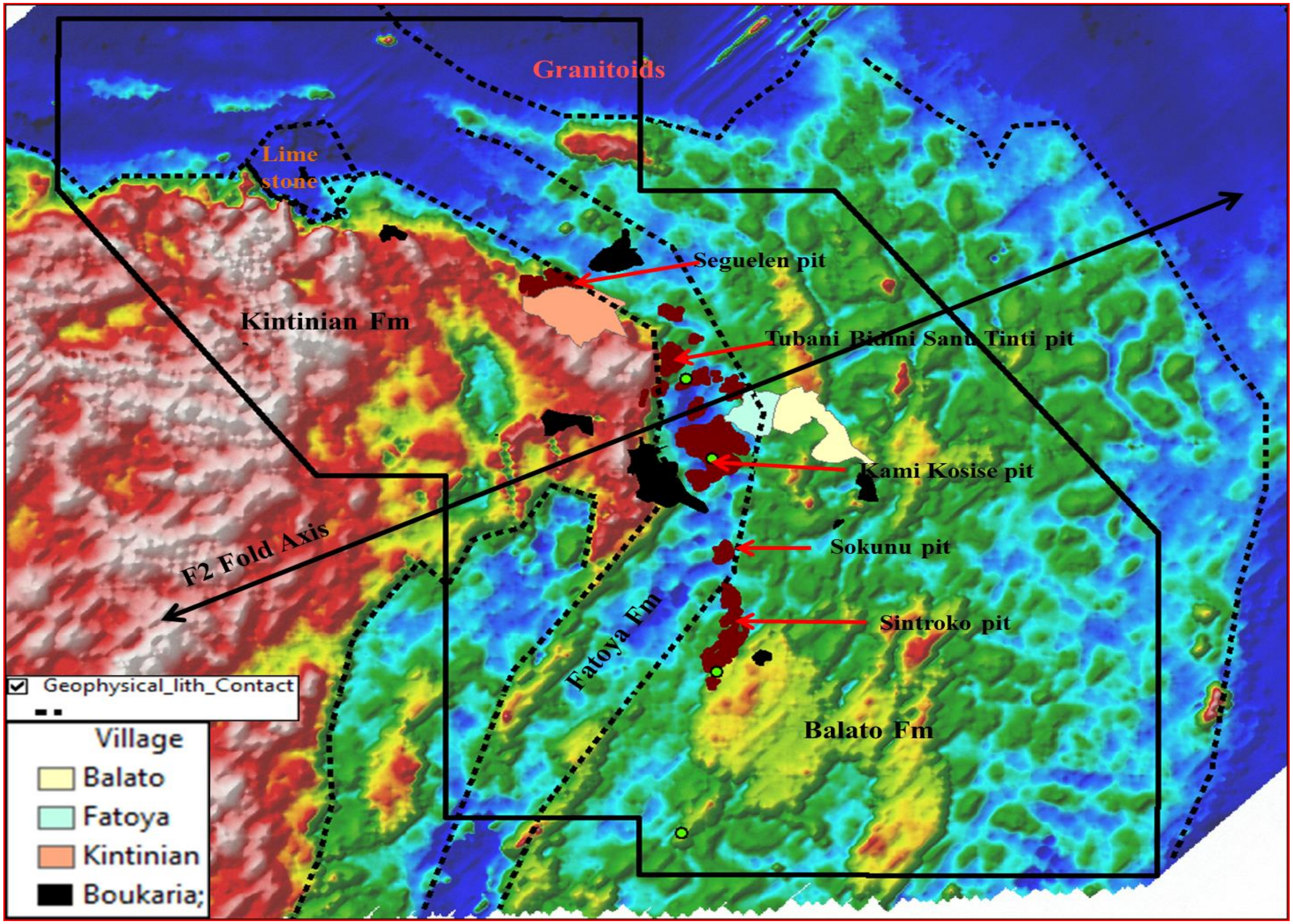

Figure 11: High resolution EM SPECTREM image showing the principally interpreted stratigraphic units and structural elements in Block1. The apparent width of the **F**atoya **F**ormation is about 1700 m (Watts, 2010 and this study, 2014).

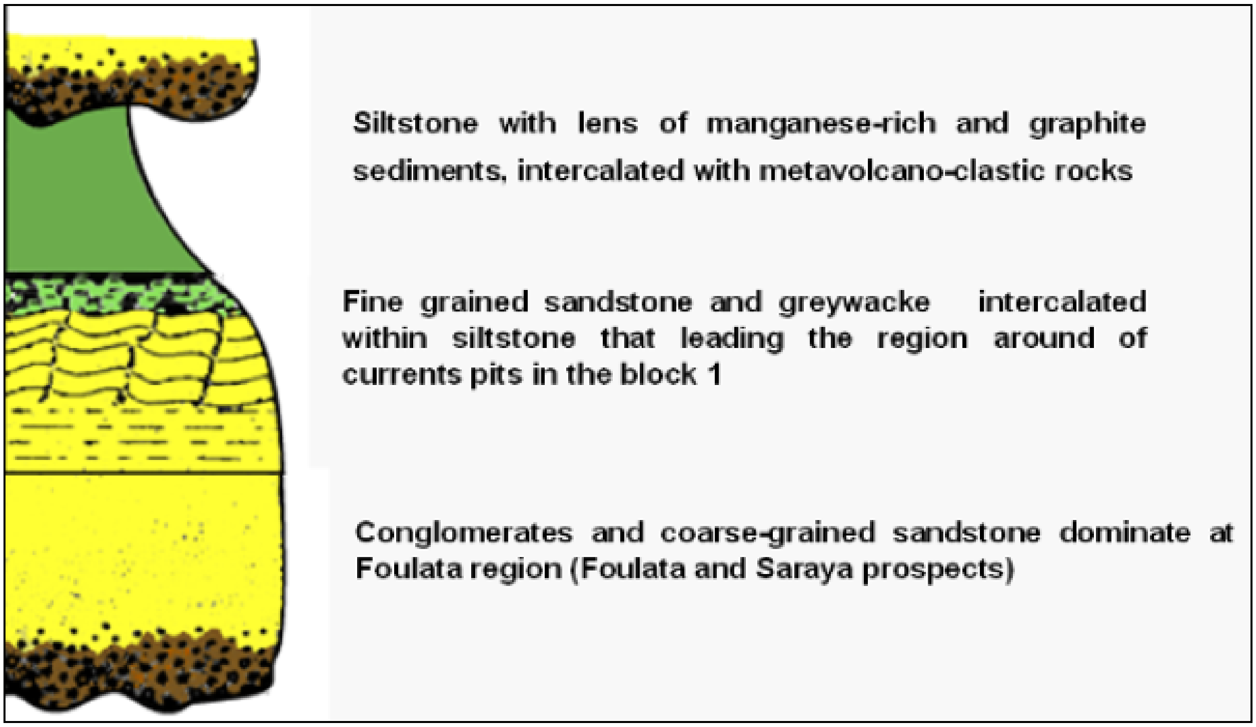

Figure 12: Generalized stratigraphic sequence – Turbidite Sequence – for Birimian Supergroup at AngloGold Ashanti concessions in Guinea (Paranhos, 2008).

4.2 Local structure

The main structural and lithological trends in the current mining area of Block1 change from a roughly N-S orientation in the southern (Sintroko-Sokunu) and central (Kosise-Kalamagna-Kozan and Sanu Tinti-Bidini- Eureka) projects to a NW-SE orientation in the northern projects (Eureka North-Seguelen-Komatiguia).

Three major stratigraphic units identified from the electromagnetic (EM) image, have been locally named according to the adjacent villages found in the mining area (**Figure 11**).

4.3 Magmatism

The magmatic intrusives are composed of mafic and felsic intrusives (granitoids).

4.3.1 Mafic Intrusives

A number of massifs occur in the area and these are capped by thick mafic sills that are probably associated with NE-SW striking narrow dolerite dykes, which are sub-vertical and are very prominent in the magnetic data. The massifs are evident at Didi, Bougourou and Mansala where the dykes can be also seen in the sediments below. These may represent the upper layers of a layered mafic intrusive of Mesozoic age but post the Birimian age (**Figure 11**).

4.3.2 Felsic Intrusives

A number of granitoids are present especially in the north-east corner of the area. Within the Franwalia rocks a weakly deformed coarse pink biotite adamellite is preserved, whereas in the south of Bougourou the granites are strongly deformed containing biotite and muscovite, as well as muscovite rich pegmatites (**Figure 11**).

4.4 Metamorphism

The metamorphic grade of the Block 1 area is very low, with muscovite and chlorite indicating that temperatures did not exceed the lower greenschists facies (Kisters and Steyn, 2010). The high abundance of albite in the rocks is consistent with low temperature metamorphism and granitic metasomatism, where the stable feldspar is albite and the Ca composition becomes incorporated in the veins (Theron and Coetzee, 2010).

According to Theron and Coetzee, the intensity of the metamorphic grade increases away from Block 1 and approaches, in places, the amphibolite facies. Carbonate-rich hills occur within the mining lease, 15 km from the current mine, to the west of a thrust fault that separates the higher grade amphibolite facies units to the west from lower grade greenschist units to the east.

4.5 Weathering Profile

The weathering profile at Siguiri is typical of a high rainfall tropical area, with deeply to very deeply weathered profiles. A total of four weathering zones can be identified at Siguiri.

- A hard ferruginous (and aluminous) crust laterite forms the cover, particularly of the areas of higher elevation, and is immediately underlain by the Mottled Zone.
- Mottled Zone is a bauxite clay zone, produced by isovolumetric weathering, containing lateritic and gibbsitic nodules and accumulations which impart a mottled appearance), then the Saprolite.

- Saprolite is a generally clay rich zone of weathered rock, composed of mixtures of kaolinite, hematite and/or goethite, gibbsite. Although more than 20% of the weatherable minerals are altered, primary fabrics are often preserved in the saprock.
- Saprock lightly weathered rock with less than 20% of weatherable minerals altered; and finally unweathered or fresh rock at depth.

The maximum depth of weathering at Siguiri is in the region of 210 m in Block1, but 100-120 m depth is more typical across most of the mining area.

Chapter 5 : Siguiri Gold Deposit

5.1 Overview of the deposit

The Siguiri gold mineralisation appears to be both lithologically and structurally controlled. Gold occurs in **low-pressure 'trap-sites'** where brittle-ductile sandstone-siltstone lithological units are deformed by compressional structures in a folded and thrusted belt. Au–bearing fluids are suggested to have been driven by calc-alkaline magmatism (Leburn, 2014).

The current conceptual model for gold mineralization in Siguiri considers that the ore bodies are structural controlled and hosted along ductile-brittle N-S and WNW-ESE striking shear zones against stock work previously modified with substantial NW-SE compression, resulting in early stage N-S sinistral faults and thrusting with a SW vergence in accordance with accreted terrains along active continental margins (**Figure 13**). This understanding opens a vast exploration potential as similar tectonic environments in different parts of the world are characterized by continued (strike and dip) and parallel shear belts hosting world class gold deposits. The figure below is orogenic gold emplaced during the collisional events, the orogeny represent a regional fluid type inherent to tectonism along convergent margins (Groves et al., 1998), which may be also geotectonically applicable to Siguiri gold deposits.

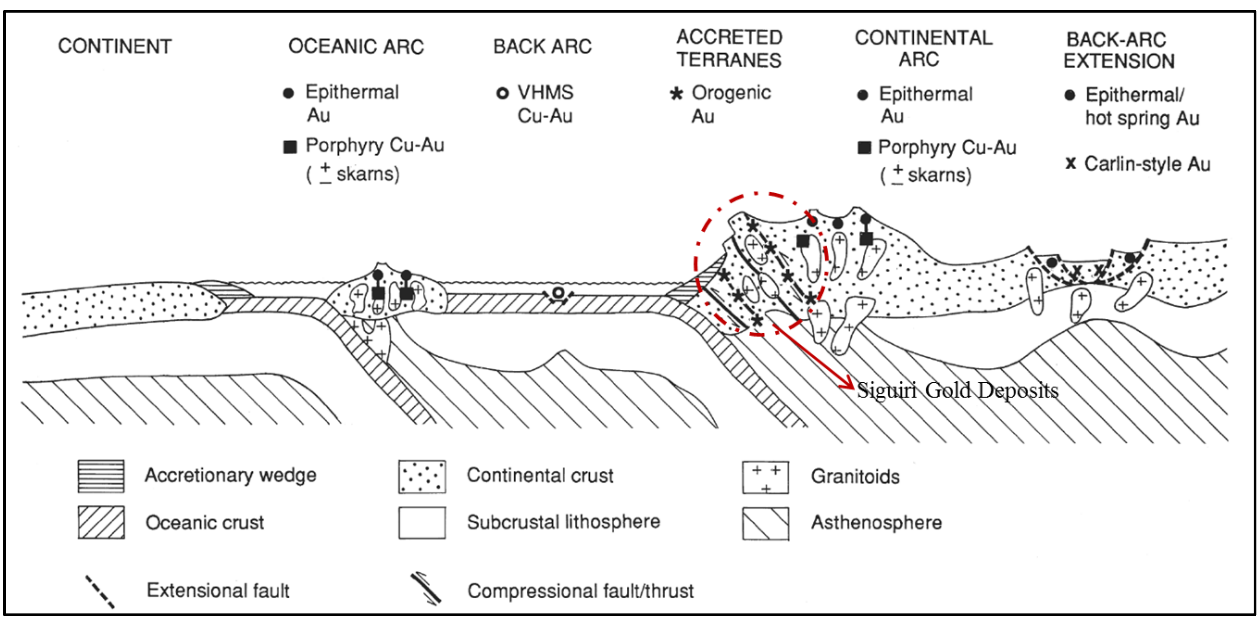

Figure 13: Supposed tectonic setting orogenic gold (Groves et al., 1998) related to Siguiri gold deposits (this study, 2014).

5.2 Deposit Types

Gold mineralization in the Birimian rocks is likely to be related to late tectonic plutonism and related to hydrothermal events that have remobilized the gold along fractures and fault zones. Primary gold deposition is epigenetic within deformed sedimentary and volcano-sedimentary rocks which have passed through several phases of deformation (Gareau and Giroux, 2014).

Three styles of primary gold mineralization have been described within the Siguiri Basin:

i. Fault and/or shear zone hosted stockwork and disseminated mineralization (e.g. AngloGold Ashanti's Siguiri Mine and Norgold's Lefa Mine)；

ii. Stockwork and disseminated mineralization within and adjacent to high level felsic intrusions (e.g. Avocet's Tri-K and Caracal Gold Sidikila deposits)； and

iii. Discrete quartz veins formed in more brittle rocks (e.g. Cassidy Gold's Kouroussa deposit).

Fault or shear zone hosted gold deposits (**Figure 13**) are the largest and most productive deposits in West Africa and in Guinea from a mining and economic perspective point of view. Within West Africa gold exploration is based on the Birimian rock assemblages where they are disrupted by long-lived regional structural systems and related faults which may have focused the flow of hydrothermal fluids and emplacement of high-level intrusive bodies. At the deposit scale the West African gold systems show considerable variability in host rock type, and structural geometry (Gareau and Giroux, 2014).

A long period of weathering and erosion has resulted in the formation of secondary gold accumulations such as recent placers or alluvial and laterite deposits, derived from primary gold sources. This deep weathering of primary shear-hosted gold mineralization has enhanced the economic viability of some of the gold deposits currently being mined in West Africa.

With the exception of Sintroko pit, the majority of the gold deposits in Block1 (Siguiri Gold Mine) are located within the **F**atoya **F**ormation which corresponds to the shear-hosted style of gold mineralisation (first type described above). The Sintroko deposit is associated with the main structure in the **B**alato **F**ormation.

Gold exploration and mining activities at Siguiri (Block1) are focused on the more economically prospective fault or shear- hosted gold deposits associated with the **F**atoya **F**ormation (**Figure 11**).

As shown from the regional geophysical map covering the Siguiri basin, gold mineralization is associated with regionally extensive northerly trending structures that cut through and deformed the late Proterozoic Birimian rocks of the Siguiri Basin. The style of deformation can vary from brittle fracturing to ductile shearing and the overall structure is normally steeply dipping. Within the structure gold mineralization is associated with quartz carbonate as stock work, veinlets or pervasive silicification and/or with associated disseminated sulphides such as pyrite and/or arsenopyrite. Gold mineralization is normally found within and adjacent to strongly deformed alteration zones. Other alteration minerals are reported for individual deposits of this type in West Africa. In additional to the structural control of the gold mineralization, certain rock types cut by the structure may be preferential or more strongly mineralized.

Two main types of gold deposits occur in the Siguiri Gold Mine:

1. Quartz-vein mineralization that occurs in meta-sediments with the more economic mineralisation associated with vein stockwork. This occurs preferentially in the coarser, brittle siltstones and sandstones. The mineralized host rocks have been deeply weathered to over 200 m in places to form saprolite mineralisation (also referred to as SAP mineralisation);
2. Laterite mineralisation (also referred to as CAP mineralisation) which occurs as aprons of colluvial or as palaeochannels of alluvial lateritic gravel adjacent to, and immediately above the in-situ quartz-vein related mineralisation.

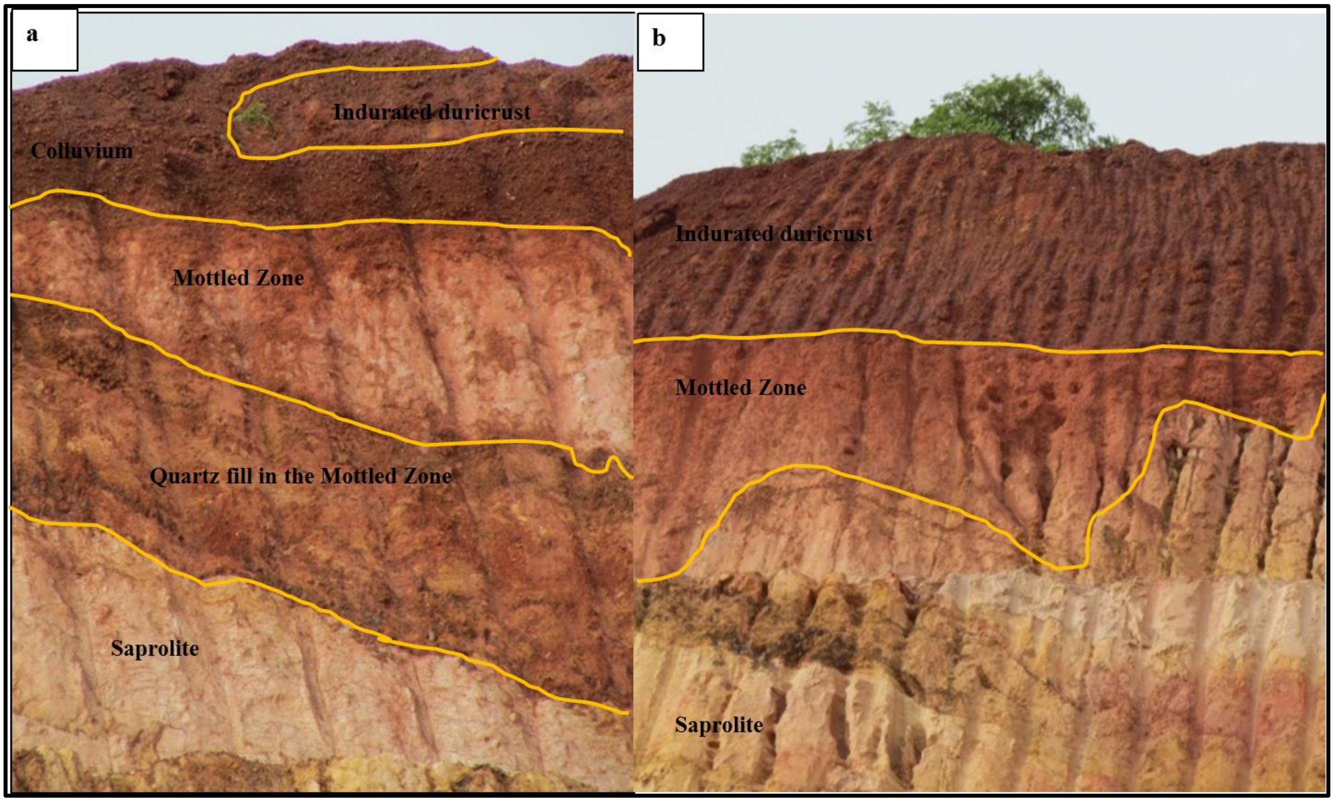

Figure 14: a. Colluvium gravel overlying indurated duricrust followed by colluvium, a mottled zone and finally saprolite; b. indurated duricrust with sharp contact to the hard mottled zone with gradational contact to saprolite (this study, 2014).

5.3 Mineralisation Styles

The Siguiri gold mine mineralisation has been identified and occurs in a number of different styles and or forms, and the mining has evolved at all the different forms.

5.3.1 Alluvial cover

Alluvial deposits typically border major drainages or may occur as older discontinuous terraces which are of interest to local orpaillage artisanal miners who pan this readily available gold.

5.3.2 Laterite

Lateritic deposits are very common in the area and typically form broad flat plateaus that are flanked by low scarps. The laterite may occur as thick plateau deposits or as thinner lateritic scree, which is sometimes partially consolidated. With the new technology using metal detectors and crusher, the cuirasse remains the best target of the Orpaillage in the area. The mining of laterite at SAG was preceded by the mining of paleoplacers that commenced in the late 1990's after the mine was re-evaluated. The gold was extracted from the laterite using a heap leach operation. Most of the mineralisation was probably related to the mottled zone at the base of the laterite. The mottled zone is often a vermiform base to the saprolite that has undergone supergene enrichment (**Figure 15**).

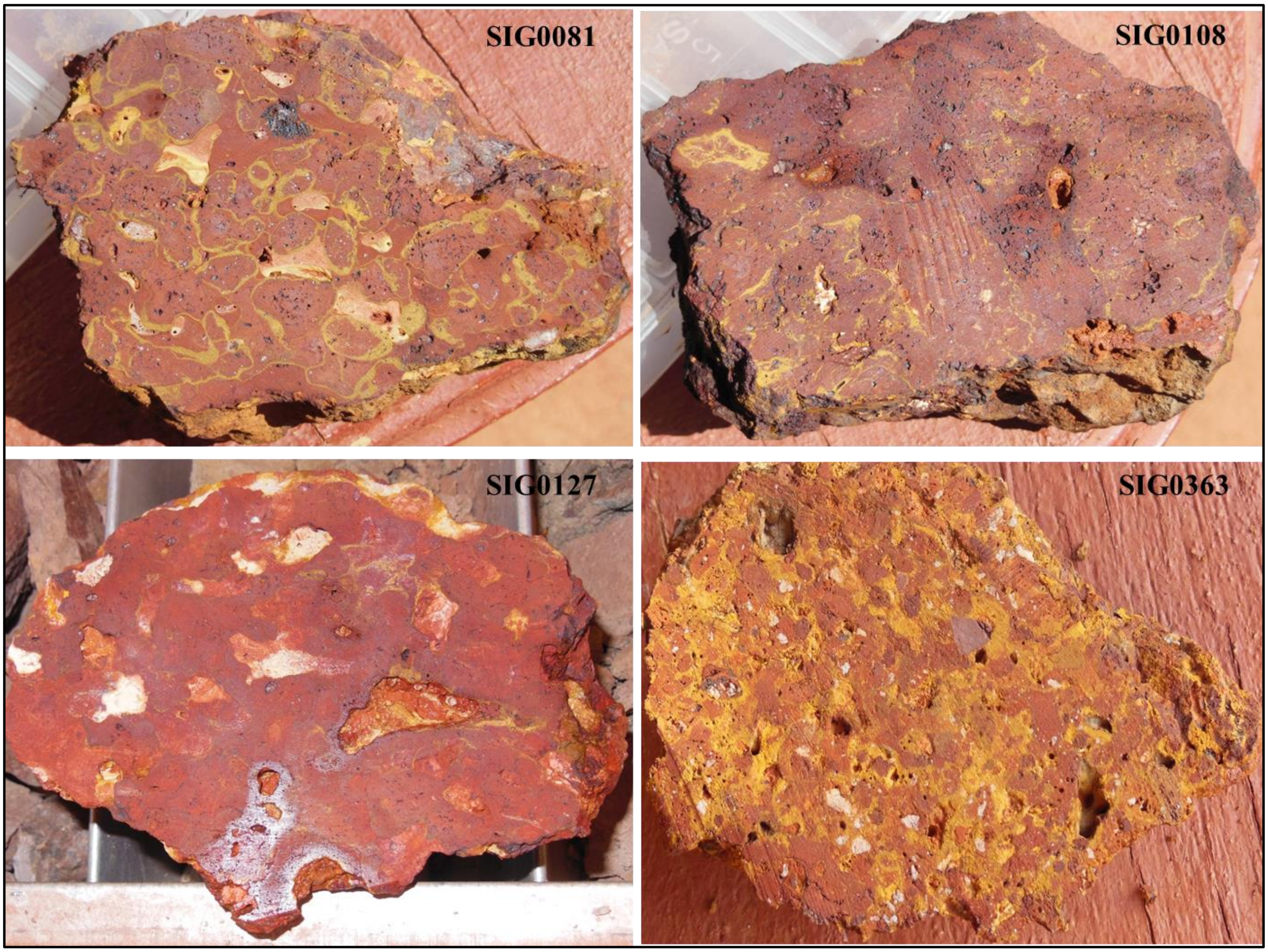

Figure 15: Pictures showing different types of cuirass collected in the Siguiri Block1 in November and December 2013. SIG0081: fine-grained cuirasse consisting of irregular ferruginous patches in a yellow-brown to orange-brown matrix; SIG0108: fine-grained clasts with minor ferruginised clays; SIG0127: vermiform cuirasse; ferruginous mottles in white/pale yellow-brown/pale orange-brown indurated saprolite; SIG0363: sample pic at the edge of rise; orange-brown sandy clays in local outcrop of cuirasse; yellow mottled along the matrix with white quartz clasts.

5.3.3 Paleoplacers

A number of pre-laterite Paleoplacers are present across the mine. The most important deposits are the Koba and Nankoba placers. Other placer, the Kosise deposit is currently being mined by artisanal miners. These deposits are essentially channels filled with clay, but contain a basal conglomeratic unit.

The initial mining in the area focused on these placers. They can be sub-divided into two units: a lower auriferous unit, or Unit I, and an upper barren Unit II.

Unit I vary from a broad blanket exceeding 200 min width to lensoid and terrace or bar morphology with well-defined channels. The broad blanket placers are more typical of the Lower Koba, whereas the channel deposits are more typical of the Upper Koba. The Lower Koba deposits indicate a more distal source compared to the Upper Koba deposits, with the Lower Koba deposits being relatively well sorted, fine-grained and rich in smokey quartz, whereas the Upper Koba contains coarser gravels, and it is poorly sorted and contains no smokey quartz. The lower Koba Unit I is 2-6 m thick and over 200 m wide in places. In comparison the upper Koba Unit I is 1-5 m thick and less than 100 m wide. Unit I fines go upwards.

Unit II is 6-10 m thick and consists of unconsolidated clays that are often lateratised and covered by 5 to 25% laterite. This zone may represent an aeolian unit that has been altered to a mottled zone. Typically this zone is barren.

5.3.4 Saprolite

Current mining activities are almost completely restricted to the saprolite zones, and these zones have provided the bulk of gold that has been mined at SAG. Gold is extracted via CIP, with the plant completed in 2005. Saprolitisation can exceed 120 m at depth, particularly along the principle structures. The chemistry of saprolite can be complicated and it is not in the interest of this report to describe them in detail.

Saprolite represents completely altered lithologies that are particularly rich in kaolinite and to a lesser extend goethite/limonite and hematite. Veining is usually relatively unaffected although all sulphides in and around the veins are oxidized and the veins typically have brown Fe-selvages around them. Although original sedimentary structures can be seen in places these are often obliterated by the weathering processes and the presence of liesegang banding.

The saprolite can be broadly separated into two units, the upper saprolite, which occurs above the sulphur redox front and a lower saprolite, which occurs below the sulphur redox front. The lower saprolite may be missing where the saprolite is thin as it appears that the sulphur redox front occurs at a similar elevation across the mine. Small amounts of sulphide in the lower saprolite may affect recoveries.

At the base of the saprolite is a transition zone, which consists of progressively less weathered, material until appoint is reached where the rock is unaffected by the weathering processes and the rock is termed ‘fresh’. This zone may also be very variable in thickness.

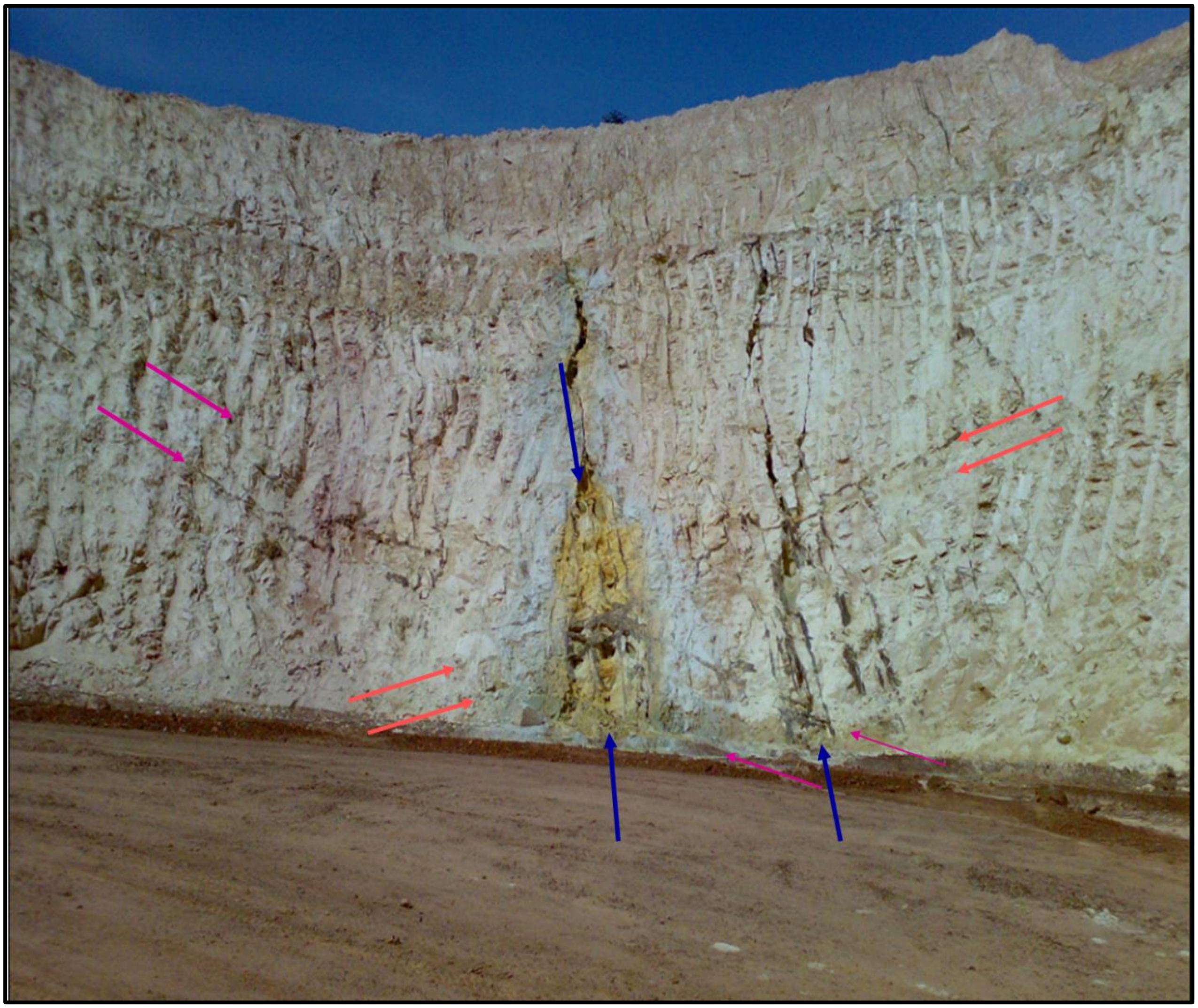

Figure 16: East-West features looking East showing the mineralisation style in the saprolite (this study, 2014).

5.3.5 Fresh Rock

A number of mineralisation styles have been identified in the fresh rock below the saprolite pits such as Kosise, Kami, Toubani, Bidini, Eureka, Sanu Tinti and Sokunu. The various styles of mineralisation also indicate that there are multiple phases of gold mineralisation. The two principle styles of mineralisation are associated with north-south structures as well as with NE-SW to E-W trending veins.

The first style of mineralisation has been termed the ‘Kosise-style’ of mineralisation and is distributed along the north-south trending structures, namely F1 faults or fault zones, showing intensely albitised and silicified units adjacent to the faults, where the sampling results clearly indicate that the gold mineralisation is associated with highly deformed albite-carbonate-sulphide-quartz veining. The grads of the veins appears to be lower than the later veins, with grades seldom exceeding 20g/t, although some visible gold has been seen in a vein, most of the diamond drill holes specially in Kami where a big campaign of fresh rock exploration, took place during the year 2013 and current year 2014.

This type of mineralisation is best seen at Kosise, although the cross-cutting Sintroko North ore zone resembles the Kosise deposits. It is likely that this form of mineralisation is more common than thought and IP targeted drilling along the north-south structures may be able to identify more places for this type of mineralisation.

The second phase of mineralisation, termed Kami-style mineralisation, is associated with NE-SW to E-W trending quartz carbon vein sets. The veins are the primary gold carriers at Siguiri and represent the most extensive mineralisation style, occurring in all the Block 1 pits to some degrees. The deformation seen in the older phase of veining is absent in the veins, although sometimes they may be folded indicating that some of them may have formed slightly earlier than others, or that there is a weak post-mineralisation structural event.

The grade of the ore zone is affected by the density of veining and whether arsenopyrite crystals are present in these veins or not. The best mineralisation appears to be related to fairly thick veins where there are at least two or three arsenopyrite bearing veins. The highest grade (up to 1.8 g/t) of this style of mineralisation is in Bidini South, where a narrow set of closely spaced veins are present. It is also evident that the largest arsenopyrite crystals seen at the mine are also associated with this deposit and it is therefore possible that arsenopyrite crystal sizes are also important to the gold grades.

The Kami-style quartz veins are essentially milky, or white, often with carbonate and or albite selvages and minor amounts of sulphides, with occasional grains of visible gold up to a maximum of a couple of millimeters in size. Carbonates may be developed on the edges of these veins, but massive sulphides are absent. These veins may also display weakly sheared contacts, which indicate that minor movement may be associated with them. These veins are axial planer veins that developed during the F2 event (Watts, 2010).

In Kami where the bedding is nearly flat clear lithological controls can be seen in these veins. The veins clearly prefer the sandier units and often form flat bedding parallel veins at the base of a fine-grained unit, with the fine grained unit acting as an aquaclude. These flat veins can also be high grade of gold and are targeted by the local miners. Along the eastern and western limbs, where the bedding is very steep, a similar process can be seen except that in these cases the veins follow the old north-south bedding planes, probably enhancing the grade of the N-S feature.

A third type of mineralisation is associated with the NW-SE orientated Seguelen ore-zone, where lower grade nearly bedding parallel ore zones dip towards the SW. This ore zone definitely contains a Kami-style component too, with NE-SW orientated high grade zones associated with the veining cross cutting the broader mineralized NW-SE orientated ore-zone. The Seguelen ore-zone can be identified as units within the shale that contain greenish alteration and fine sulphides, both, pyrite and arsenopyrite, as well as small magnetite grains. The exact relationship of the Kami-style vein mineralisation and the disseminated Seguélén-style of mineralisation and their age relationships are currently unknown, but based on the sulphides present, the mineralization may occur in a similarly time.

The Sanu Tinti-style of mineralisation differs from all previous styles of mineralisation in that it is a breccia hosted type of mineralisation that does not require any veining. The mineralisation is associated with a sedimentary, possibly volcaniclastic unit up to 50 m thick, and it has been subsequently injected by hydrothermal fluids, possibly related to a nearby fault, to form pyrite, magnetite, pyrrhotite, chalcopyrite, and tourmaline into the breccia.

The final style of mineralisation that has been noted is associated with the Old Sintroko ore zone, which crosses cuts bedding and plunges towards the SW. This ore-zone consists of a highly silicified and albitised unit between 1 and 12 m thick, often containing magnetite layers, which are partially replaced by pyrrhotite or pyrite. Magnetite is not always present, although pyrite is and arsenopyrite also usually present, together with some pyrrhotite. The physical appearance, with the exception of the magnetite, of this style of mineralisation is similar to that seen at Kosise, however the architecture of the ore zone differs with the Kosise ore zones being sub-vertical, bedding parallel or near parallel, and the Old Sintroko ore zone which dips at angles between 80-50˚ towards the SW and clearly cross-cuts bedding (Watts, 2010):

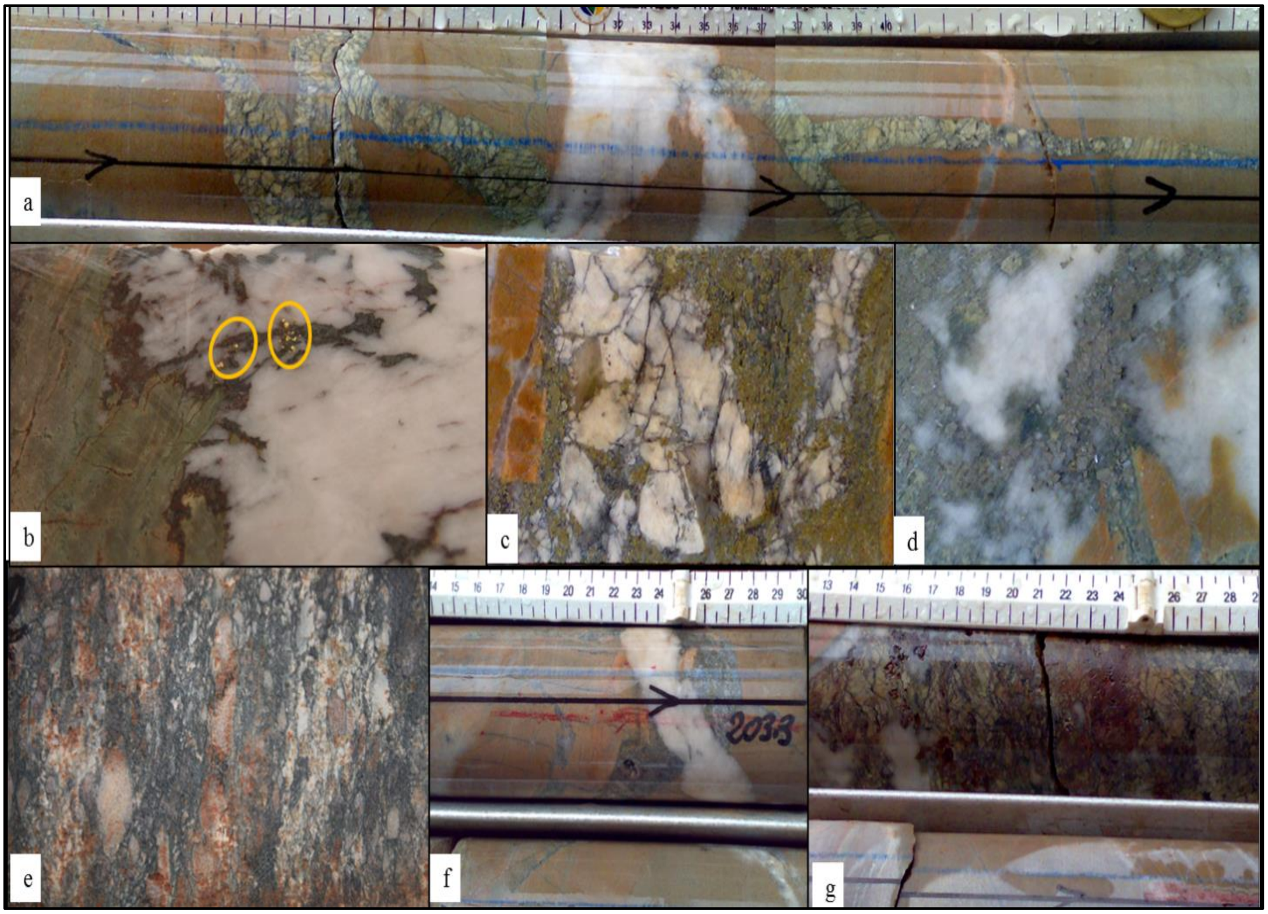

Figure 17: Pictures showing the mineralisation style in the wall rock at Siguiri Gold Mine (Wall rock study, 2010 and 2014). a. Quartz carbonate (milky quartz vein) and albite-sulphide vein relationships; b. Gold visible in white quartz vein and siltstone with chlorite alteration; c. Quartz carbonate with pyrite dominated veins; d. Sulphide arsenopyrite veins; e. Associated brecciation with narrow quartz veining and low sulphide, f. Albitised siltstone cross cut by quartz carbonate veins, g. Sulphide and pyrrhotite with white quartz veining.

Chapter 6 : Regolith Mapping

6.1 Background

Mapping the regolith terrain, it is advantageous to develop models in order to explain and predict the distribution of regolith types, and explain the landforms. The models require a holistic 4D approach, drawing on information about present and past geomorphological processes, past climates, tectonic history and geology. Landscape models can become a precursor to exploration models, to explain the distribution of regolith materials, and differences between the regolith and bedrock geochemistry. One such model is proposed here. It describes how a partially stripped, partly preserved regolith terrain can evolve through a sequence of alternating regolith formation and dismantling events, resulting in a complex regolith terrain similar to those found in areas of West Africa and Western Australia.

In regolith-dominated terrains, however, it is rarely the rocks that are sampled, but the regolith. The near-surface geochemistry results often dictate the life and direction of an exploration project, particularly during the initial and final phases. High assay values of samples are most often treated as the anomalies and become the focus of further work, while low assay values are treated as insignificant and these areas are consequently ignored. The word “anomaly” is all too frequently misused, and has become synonymous with “high assays” and rarely used in its literal meaning of “abnormal, or irregular” (Fowler & Fowler, 1978). Higher assays are not always anomalies, and low assays need not be insignificant. Lateritic weathering can result in the concentration of Au and its pathfinder elements within the lateritic duricrust. Erosion and transportation followed by deposition will result in a redistribution of weathering products, which over time can be further modified (Freyssinet, 1993).

In recent years, the importance of understanding where we are in the landscape, and what are we sampling, has resulted in considerable research and publications, especially within Australia through the work of CSIRO-AMIRA and the Cooperative Research Centre for Landscape Evolution and Mineral Exploration (CRCLEME). There are many strong arguments and considerable evidence (Butt & Zeegers, 1992) that, when exploring in terrains with complex weathering and erosion histories, surface geochemical sampling will not deliver a set of results that only reflect changes in the bedrock geochemistry.

Regolith mapping has gained greater prominence and wider acceptance and usage within the mineral exploration community over the last decade. However, it is still not a routine procedure, despite many benefits it can bring to an exploration program in regolith-dominated terrain. Some explorationists still naively believe that, when looking for very large ore bodies, there will always be strong geochemical responses and therefore regolith mapping is unnecessary and irrelevant.

A correctly structured landform and regolith map will enable visualization of the terrain so that appropriate sample types and sampling intervals can be selected, and results sensibly interpreted and followed up, taking into consideration the “regolith factor” as well as physical dispersion processes. Importantly, the most anomalous samples (not necessarily highest assays) can be identified.

Ideally, Landform and Regolith maps should be produced at the start of an exploration program, thereby assisting with the following:

- review of historical data, checking if all anomalies have been identified and investigated appropriately,
- planning of orientation surveys (if necessary),
- selection of appropriate sample media and sample density,
- geological mapping through the identification of outcrop occurrences,
- interpretation of remote sensing data , and
- ground-truthed follow-ups of aeromagnetic features.

6.2 Mapping approach

The approach of the regolith sampling, geochemical analysis, regolith map compilation, and discussions is enhanced by dealing with the relationship of regolith chemistry to different regolith-landform types and regional geology.

For exploration purposes, the Siguiri landform and the regolith terrain is divided into four groups or regimes. These are defined as follows:

Cuirasses regime (comprising ferruginous weathering products at or very close to surface),

Erosional regime (prospective lithologies at or very close to surface),

Depositional regime (prospective lithologies masked by sediments > 5 m to possibly 20 m thick), and

Residual regime (an in-situ non ferruginous soil developed directly over weathered lithologies).

The regolith classification is based on the landform position and composition of regolith. Apart from showing the distribution of various regolith types, regolith maps are also showing the genetic relationship between different regolith types.

Landform and regolith maps are planned to be completed at this stage of the exploration cycle at Siguiri mine. They are used in conjunction with the results soil sampling, geophysics surveys conducted and drill programs completed with the view to understand whether or not:

- All anomalies have been identified, and all the probable sources have been investigated;
- New anomalies can be identified;
- Geochemical sampling techniques used have been appropriate;
- Geochemical sample spacing has been adequate and complete; and
- What lessons have been learnt from this program and will can be applied to future work.

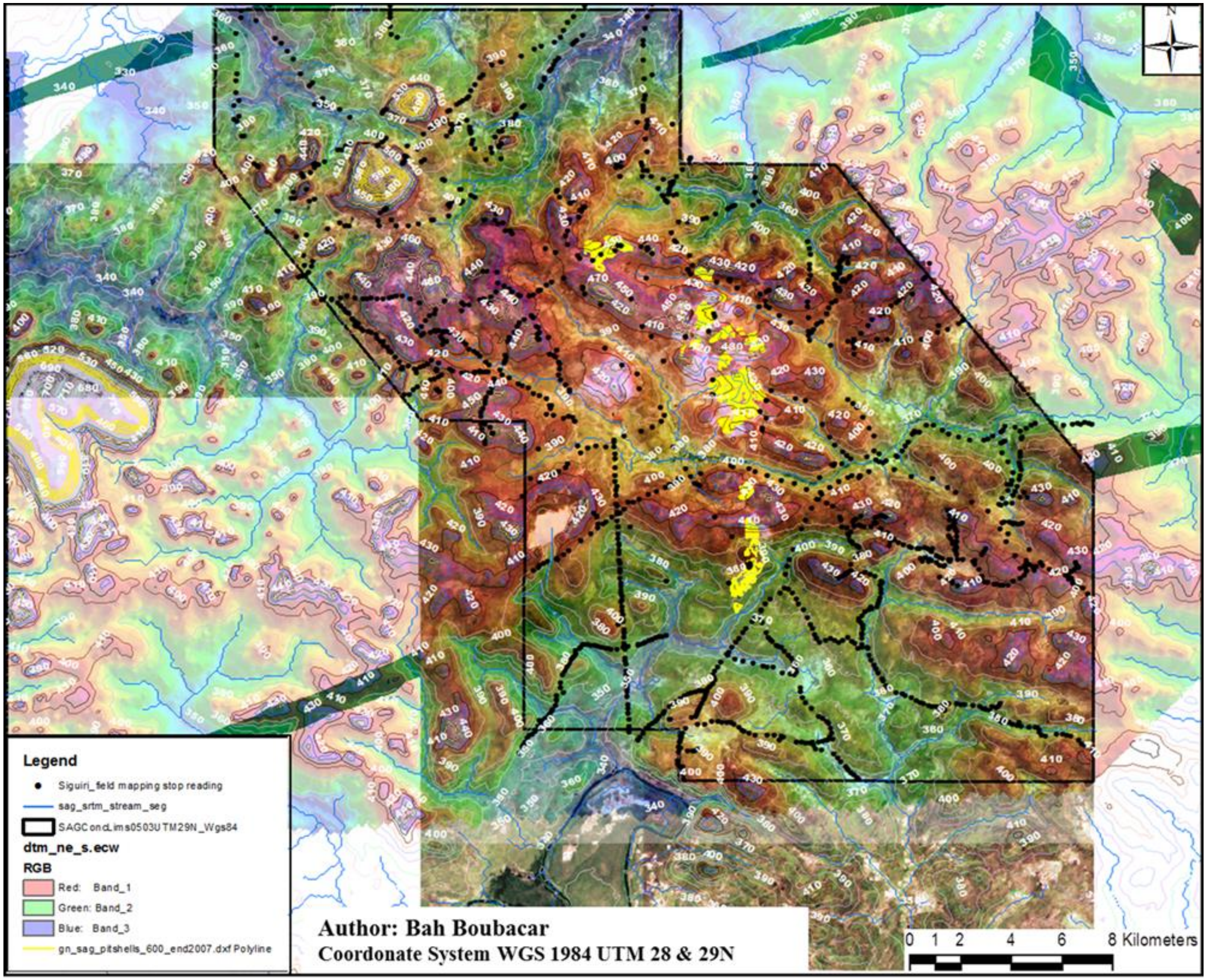

Figure 18: Map showing the extent of the field coverage overlain on Block1 topography contours (Background: Arial photo digital elevation model (DEM) image, this study, 2014).

6.3 Sampling

The sampling method consists of recording the logging of track and trail locations across both lower elevations and topographically elevated areas. A total of 1,466 points were recorded within Block1 over a period between November and December 2013. These field activities were conducted with assistance and direction given by Dr Marian Skwarnecki.

Numerous cuirasse hand specimen samples were collected for assaying purposes and were cut with a diamond saw to facilitate taking photographs.

A particular attention is made to the quartz vein or quartz lag due to their relation with gold. The quartz vein is driving the fluid during the hydrothermal process.

All recorded data captured in an excel spread sheet and plotted in ESRI ArcMap™ (version 10.2) with refers to the datum WGS 84 and 29N.

6.4 Mapping Results

The outcome of the field work is a regolith map produced by Dr. Skwarnecki. ArcGIS 10.2 software is used see (**Figure 22**) to generate the collected information (**Table 2**) together with soil sample description and elevation contours over the area.

Table 2: Description of the stop reading reference with WGS84 UTM 29N (this study, 2013)

Site	Easting	Northing	Description
SIG1-0001	466362	1274818	ferruginous cuirasse developed in polymictic colluvial gravel; mottled clays underneath
SIG1-0002	466343	1274797	breakaway; cuirasse developed in colluvium
SIG1-0003	466359	1274852	artisanal workings in colluvial gravel; gravel is ferricrete and quartz
SIG1-0004	465009	1274207	cuirasse with polymictic clasts; mottled; yellow brown; proportion of clasts decreases downwards - ?developed in alluvium
SIG1-0005	461754	1270992	colluvial gravel overlying cuirasse in colluvium; artisanal workings in the gravel
SIG1-0006	460722	1274499	pit in cuirasse in colluvium; very poorly sorted polymictic colluvial gravel - quartz; ferricrete; ferruginous saprolite
SIG1-0007	457263	1280985	low hill; cuirasse with poorly sorted clasts - polymictic: quartz; ferricrete; ferruginised clays
SIG1-0008	462862	1281363	top of low steep hill; cuirasse in colluvium: rounded ferruginous clasts cemented by goethite and hematite
SIG1-0009	462828	1280935	artisanal workings in clays and gravel and locally into underlying saprolite
SIG1-0010	461783	1281855	cuirasse with poorly sorted rounded clasts of earlier cuirasse; quartz; ferruginous lithic
SIG1-0011	458902	1283037	cuirasse cementing colluvium on valley side; some plant roots in the cuirasse; clasts: quartz; ferricrete; earlier cuirasse
SIG1-0012	458888	1282982	a/a but with angular lithic clasts - outcrop possibly not too far below surface
SIG1-0013	458922	1283021	saprolite outcrop on hill slope; purple/orange-brown after ?chloritic schist
SIG1-0014	459477	1284894	quartz vein outcrop in gravel along valley; quartz vein is associated with strongly indurated (silicified) schist; vein trends E-W and dips moderately N
SIG1-0015	459469	1284887	pit in cuirasse: cemented gravel; cuirasse overlies mottled clays and gravel
SIG1-0016	458690	1286100	thin cuirasse cementing gravel underlain by white transported clays
SIG1-0017	458905	1287420	cuirasse cementing gravel (quartz and ferricrete); some parts relatively fine-grained and well-sorted-equigranular; rare lithic clasts
SIG1-0018	458548	1287542	cuirasse cementing clays and relatively fine-grained gravel: quartz; ferricrete; rare lithic
SIG1-0019	457916	1283103	colluvium overlying pale pinkish brown transported kaolinitic clays with ferruginous clasts; overlies orange-brown/yellow-brown clays with ferruginous clasts
SIG1-0020	457878	1283122	saprolite overlain by cuirasse developed in colluvium (clay and gravel); very irregular contact
SIG1-0021	457983	1283116	cuirasse developed in gravel: quartz; lithic; ferricrete clasts
SIG1-0022	455610	1274986	fairly flat area; cuirasse cementing colluvial gravel and previous cuirasse clasts; clasts: ferricrete; rare quartz; rare ?lithic
SIG1-0023	455059	1275803	cuirasse cementing colluvium; rounded ferruginous clasts cemented by orange-brown matrix; gently sloping and flat area
SIG1-0024	455467	1279209	cuirasse cementing colluvium on low rise; clasts mostly ferruginous with rare quartz; goethite coatings along fractures
SIG1-0025	455589	1279179	gentle slope; ferruginous gravel eroded from cuirasse upslope
SIG1-0026	455805	1278877	grey transported clays; local mushroom termite mounds
SIG1-0027	455112	1279996	low ridge; cuirasse developed in colluvium; orange-brown/yellow-brown clasts in mottled matrix; clasts are matrix-supported
SIG1-0028	452071	1278607	backslope of breakaway; cuirasse in transported gravel and clays; clasts: ferricrete; rare quartz; rare lithic
SIG1-0029	451480	1277934	small knoll; very fine-grained indurated (silicified-ferruginised) orange-brown/black saprolite
SIG1-0030	451544	1277895	loose blocks of cuirasse on strongly indurated black/orange-brown schistose saprolite; cuirasse contains blocks of bedrock and some quartz

Soil samples were split according to the following general groups: bedrock; colluvium; duricrust; ferruginous gravel; mottled zone and transported clays.

Ten geological units have been defined to classify the Siguiri Block1 regolith (**Figure 19**)

- Unit1: Low hills rise on Niono plateau
- Unit2: Niono plateau
- Unit3: base on Niono plateau and Isenberg
- Unit4: Upper slope incision into Niono plateau
- Unit5: Lower slope incision into Niono plateau

- Unit6: Middle plateau
- Unit7: Low Scarp
- Unit8: Flood plain (lower plateau)
- Unit9: Incision into flood plateau
- Unit10: Outcrops

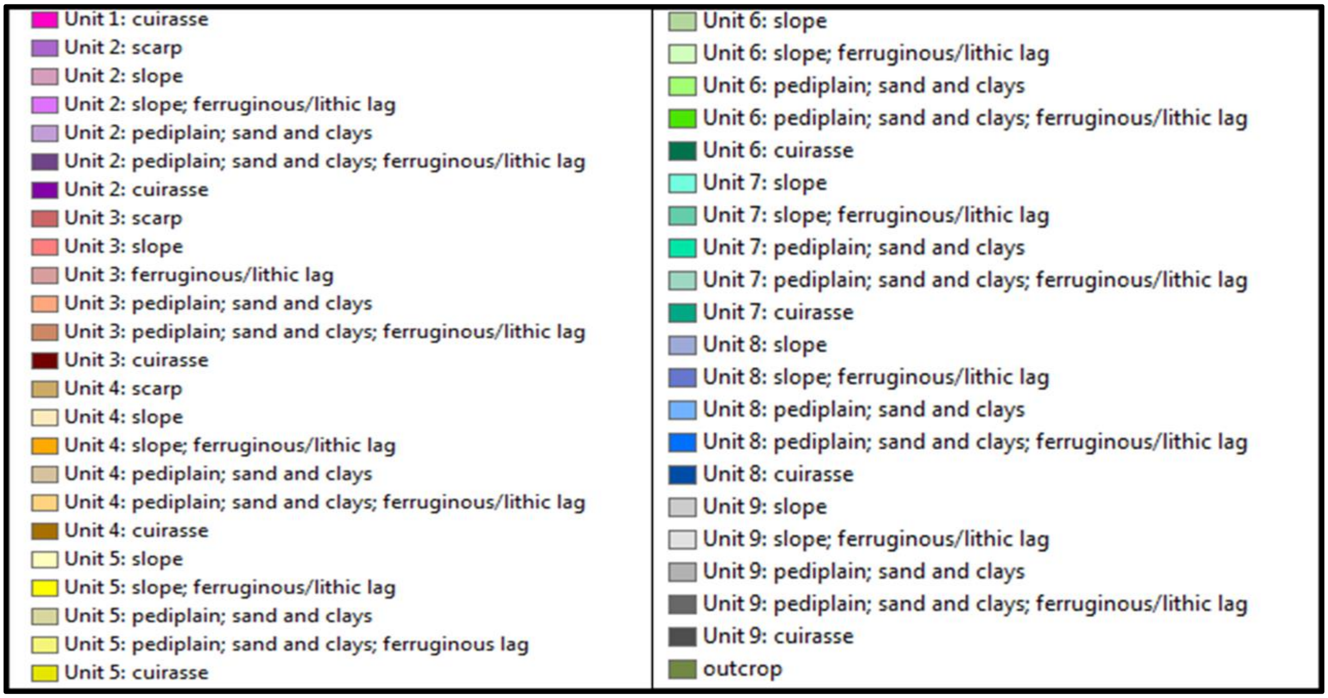

Figure 19: Siguiri Block1 regolith, geological units classified and reported by Skwarnecki (2014).

A point to note is that more residual soils have been identified over the area than initially anticipated. Approximately 30% in-situ residual cover and 70% transported cover was estimated for Block 1 after the field investigation. Outcrop is common in the underexplored north western area. There is occasional cuirasse present but bedrock clasts are extensive so it is considered that the bedrock will be close to surface in this area.

The Siguiri landscape is a combination of multiple surfaces and slopes. However the typical African bauxite surface is not present within the area visited. Instead the ferruginous duricrust at Siguiri occurs superimposed on an already truncated weathering profile. As such, the uppermost parts of a classical lateritic profile are missing and regolith profiles such as shown in (**Figure 20**) are commonly developed (Skwarnecki, 2014).

Figure 20: Photographs 'A' and 'B' showing typical exposures seen in outcrop (December 2013). 'A' is a strongly indurated ferruginous duricrust developed in transported material. A coarse-grained, clasts-rich upper colluvium grades downwards into a less indurated, finer matrix with sparser clasts. Alluvium at the base of the section is indurated predominantly by silica rather than iron oxides. 'B' photograph shows a cuirasse with polymictic clasts.

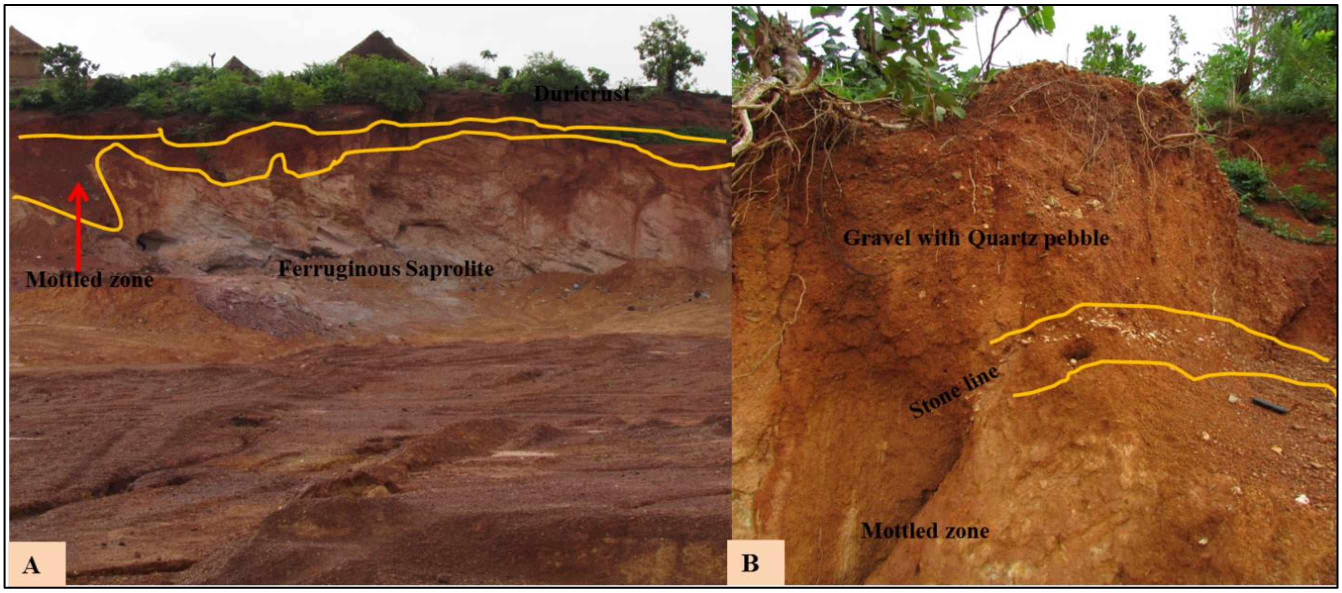

Figure 21: Section view through photographs 'A' and 'B'. 'A'– represents hard duricrust with spotted mottled zone and ferruginous saprolite. 'B' is a picture showing a stone line derived from and overlain by gravels and underlain by a mottled zone the quartz vein is cut by the Orpaillage at the left side.

From regolith and landform mapping conducted and in conjunction with the evaluation of the surface geochemical sampling data the following information has been revealed:

i. Many of the surficial regolith materials comprise transported sandy-clays and ferruginous cuirasse developed in colluvium. Surface gold and arsenopyrite (Au-As) anomalies generally reflect secondary/tertiary dispersions producing broad and patchy surficial re-distribution of Au-As in a variety of regolith material through alluvial-colluvial processes (e.g., detrital gold particles in ferruginous cuirasse or the quartz component of gravel which can give rise to low-level geochemical anomalies).

ii. Previous alluvial mining and current artisanal operations (such as dredging along drainages and digging into the duricrust using metal detector) has also affected the patterns of surficial geochemical dispersion through contamination.

As a consequence, surficial Au-As anomalies may not reflect underlying geology and genuine evidence of underlying Au mineralisation, except where surficial regolith is residual. Lateral geochemical dispersion in regolith over mineralized primary structures appears to be limited and thus geochemical haloes in regolith will be relatively narrow.

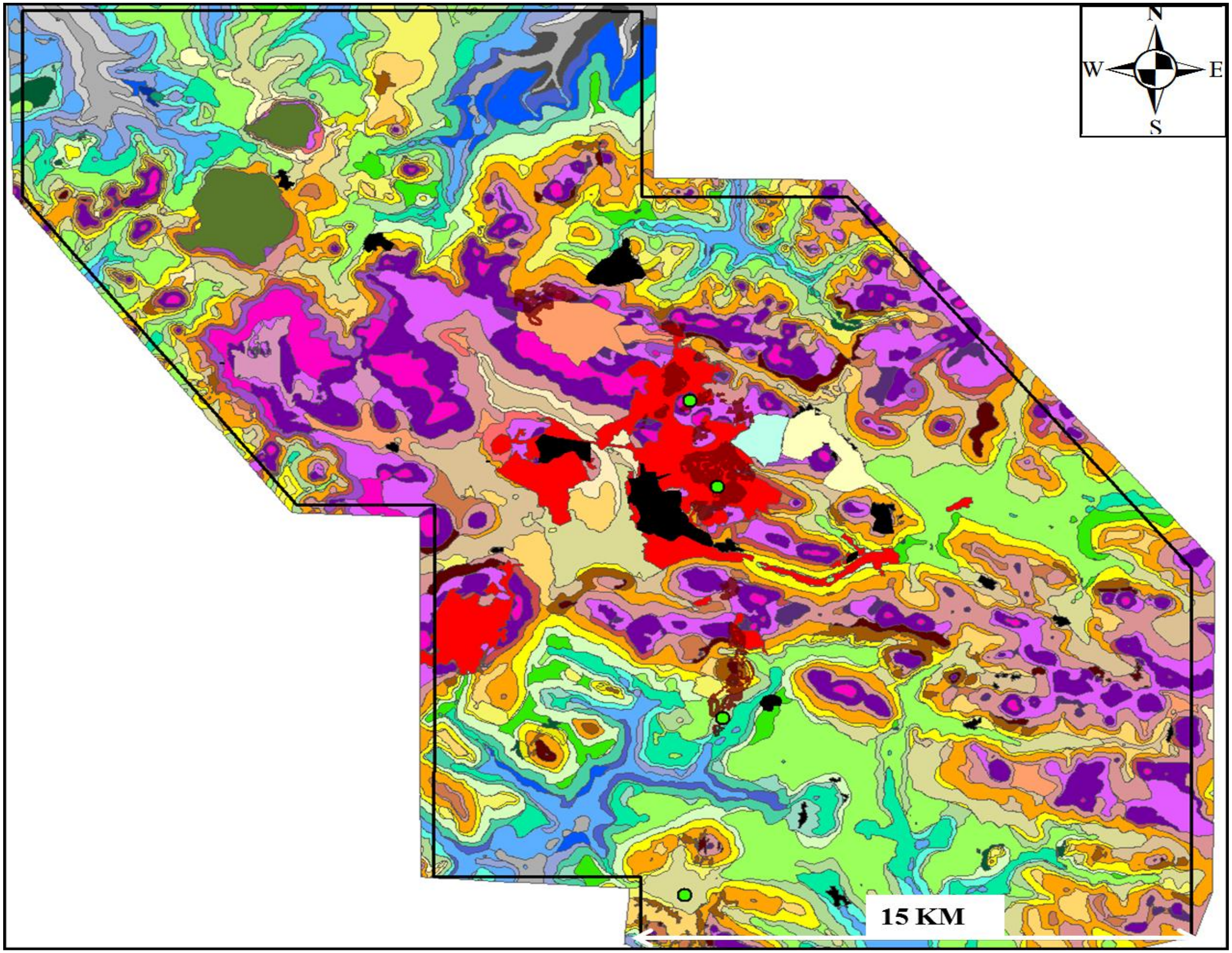

Figure 22: Siguiri Block1 Regolith map (Map and reported by Skwarnecki, 2014) the map legend is referring to the (**Figure 19**).

6.5 Targets from field mapping

Block 1 target generation workshop was held in November 2013 where new target areas were identified and ranked (low, medium and high) based on their relative prospectivity. Targeting vectors included structural trends, lithological contacts and preferential lithologies.

Field assessments, by regolith mapping, were undertaken to establish the validity of target generating vectors.

The initial aims is to conduct a field assessment of each target, by detailed target mapping, to establish the nature and validity of target generating vectors such as geochemical anomalies and/or confirm the geological interpretation of structural trends and lithologies.

The area maps are indicated in the Figure below.

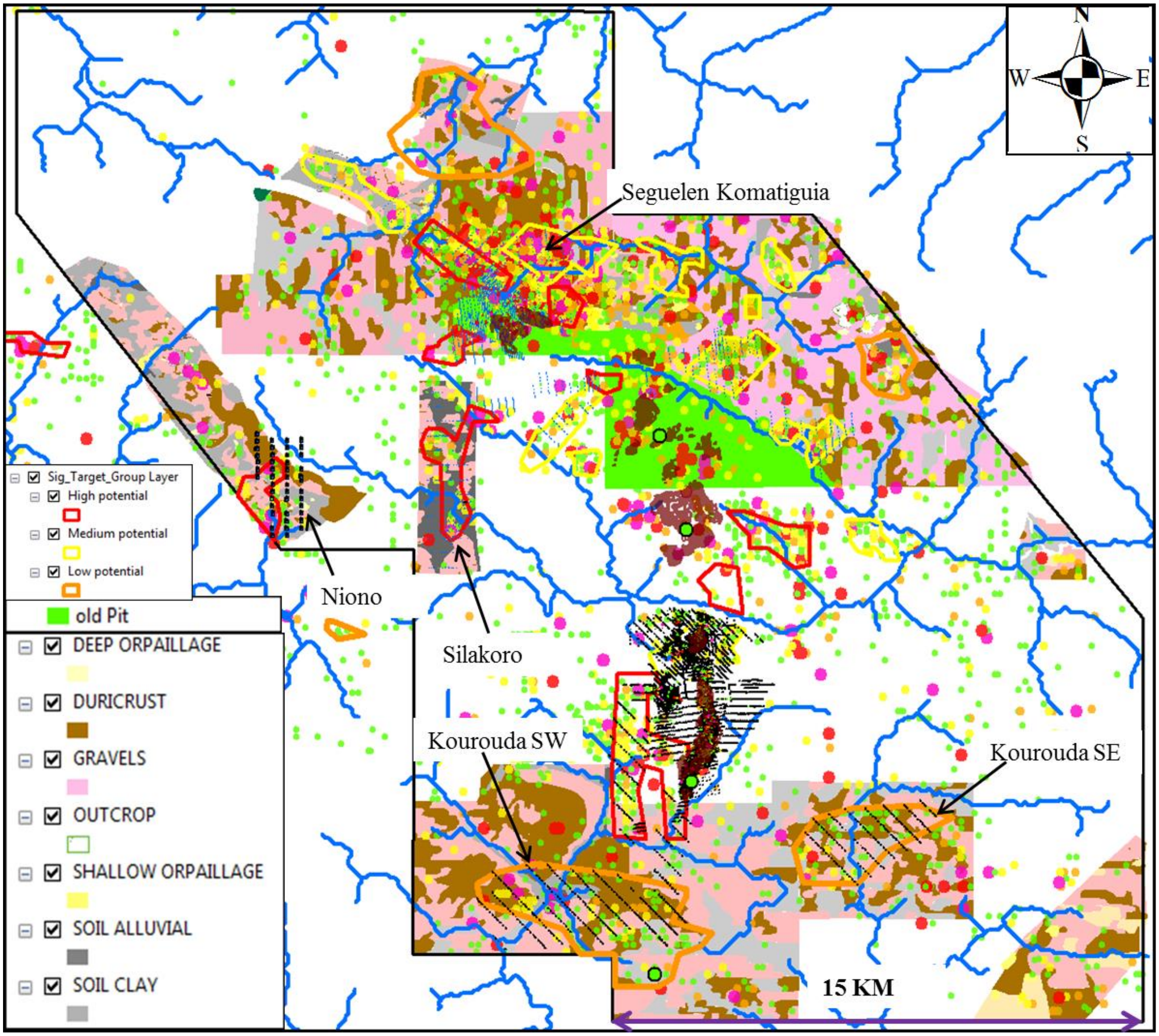

Figure 23: Plan showing the regolith map on the generated targets with the Siguiri Block1, the black dots represent the drill holes (this study, 2014).

Chapter 7 : Result of Soil Geochemistry

7.1 Surface Sampling

Soil samples collected every 50m along 200m spaced grid lines oriented either east-west (as at Kourouda SE and Kourouda SW) or north-south (as at Balato, Niono, Seguelen and Silakoro) targets. To date a total of 59,788 samples have been collected during this period, representing 95 % coverage of Block1 mining license. This total excludes historical 'track and trail' data collected before grid sampling became the accepted procedure.

Among the soil geochemistry, targets generated during this campaign are the core of this thesis and they are outlined in **Table 3** and on map (**Figure 24**).

Table 3: Table shows the selected targets to be ground-truthed. Their calculated coefficients of correlation between Au and As are also indicated.

Targeted Area Name	Total Samples	5% of the Samples	QA/QC	Coef of Correlation AuVsAs
Balato	5366	268		0.056718657
Kourouda SE	2126	106		**0.873985165**
Kourouda SW	5556	278		0.112821358
Niono	1325	66		0.0034059
Seguelen	7124	356		0.098572723
Silakoro	1401	70		0.015881421
Total	**22898**	**1145**		

Anomalous gold and arsenic values were identified in most parts of the Block1. Anomalous gold values ranged from 20 ppb to 45,000 ppb and from 20 ppb to 15,000 ppm for arsenic. Most of the anomalous geochemical targets have been tested through air core drilling and no consistent economic intercepts were delineated.

7.2 Analytical work

Due to inconsistencies in description the Siguiri soil geochemistry data was re-interpreted by Dr Skwarnecki to produce a more coherent percentile data set. Major gold soil anomalies were noted in the north of Seguelen, and west of Sintroko. The soil anomalies in the north of the Kourouda and Kourouda south west area were considered to be of low confidence and it was suggested that they shall be re-sampled.

The arsenic data set was considered to be more coherent, although it was found that data is lacking in much of the northwestern area. Several potential north-east trends were identified in the arsenic data, and especially in southeastern area (**Figure 25**).

Based on the assay results of samples received from SGS laboratory, the assays are loaded into the database. The assay Table is extracted from the database and interpreted using ArcGIS 10.2 software. In total, seven classes ranging between 0 and 45,080 ppb are defined for gold and three classes ranging between 0 and 15,160 ppm are defined for arsenic as shown in the legend of

Figure 24 and **Figure 25** respectively.

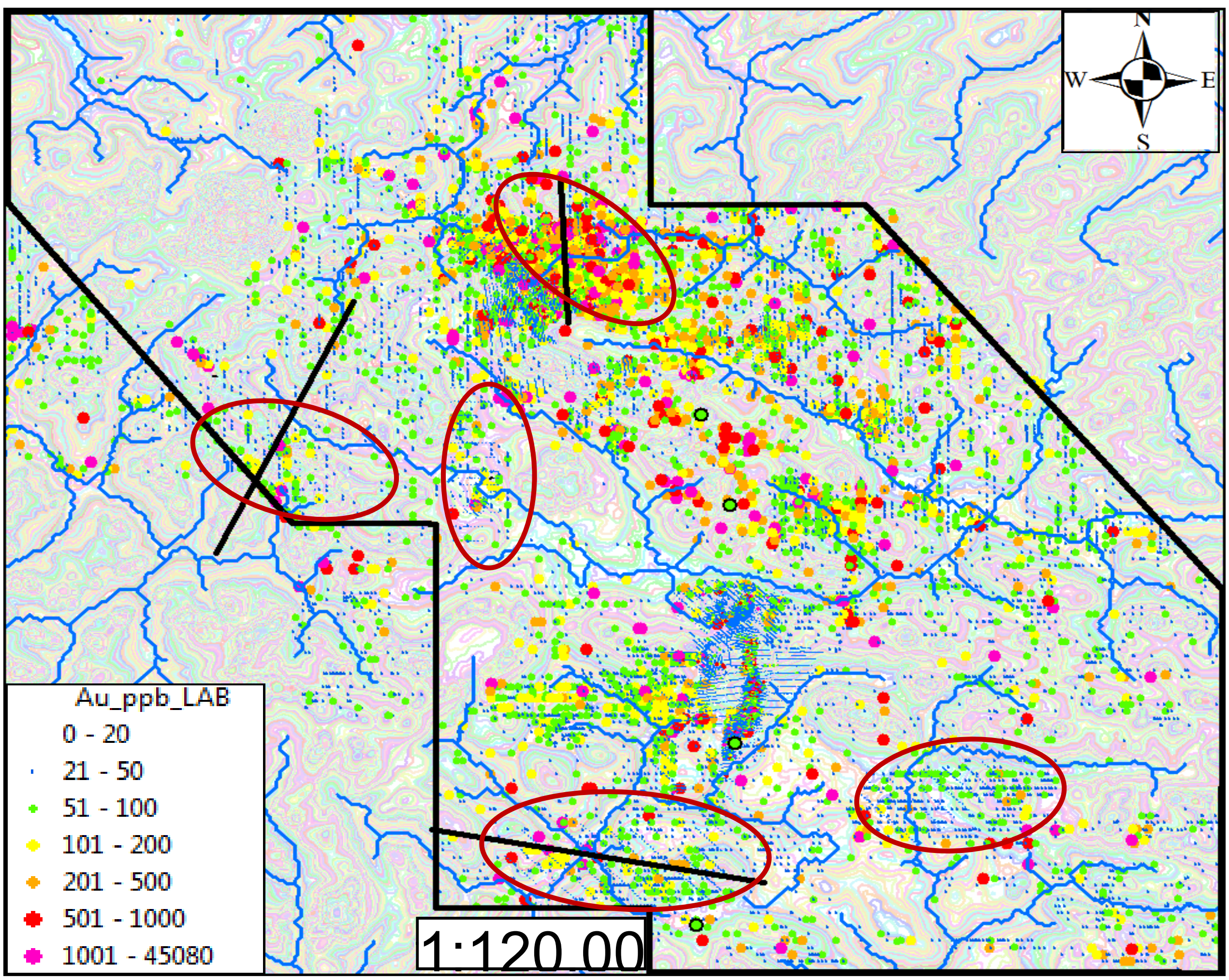

Figure 24: Surface geochemistry for gold and drilling are plotted over the Block 1 topographic map. The red circles represent the drilled targets with the drill holes shown as blue dots. Drainage rivers are also indicated in blue (this study, 2014).

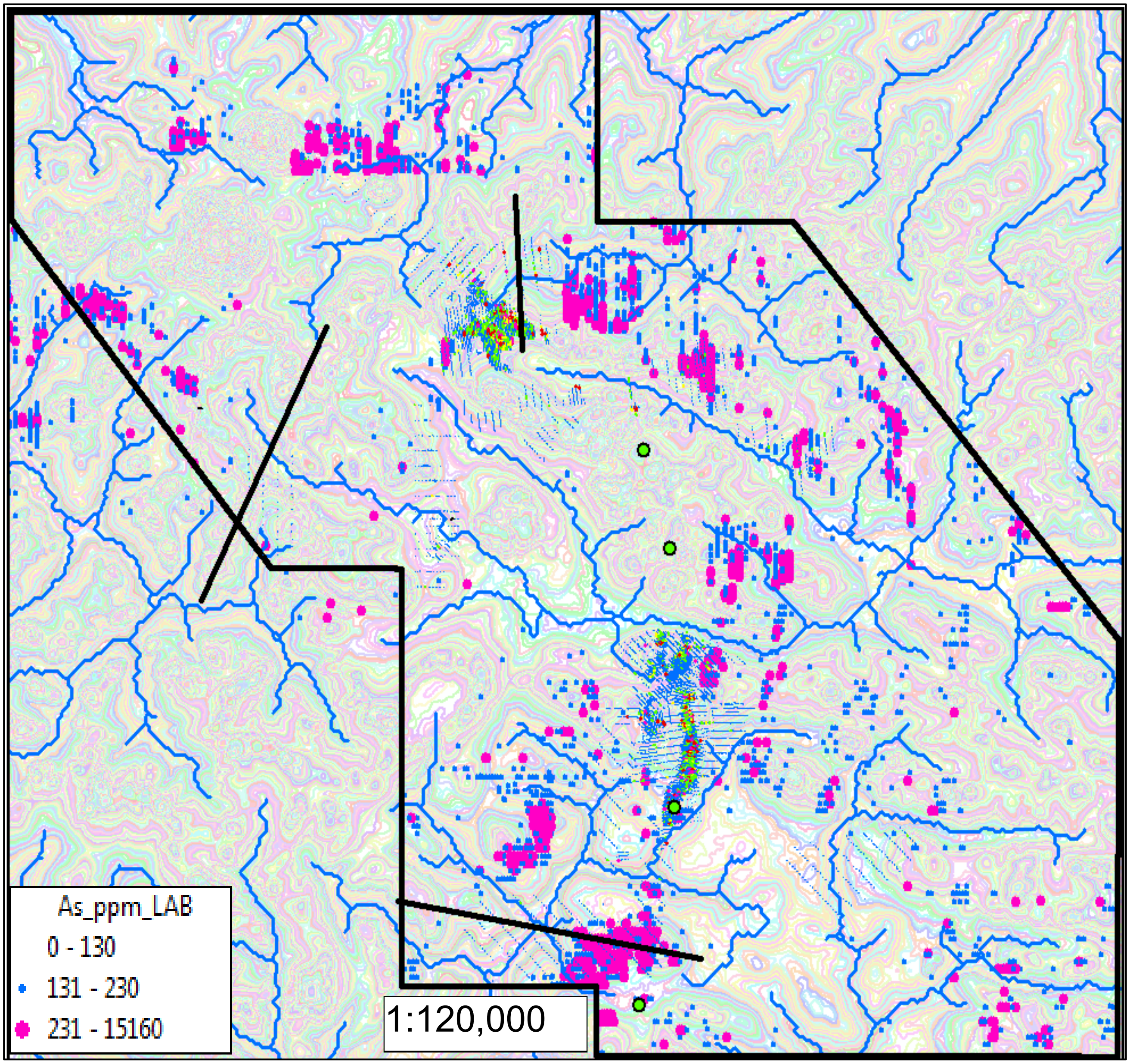

Figure 25: Surface geochemistry for Arsenic (As) over the topographic and drainage map for Block1 (this study, 2014).

7.3 Data Validation

All soil sampling data are extracted from fusion database and re-imported into local Microsoft Access. Data validation consists of removing all the zero and negative values. The negative values represent either insufficient samples (IS), samples missing or samples which were not reported in the assay results and loaded into database.

The following is a discussion of the various data validation steps taken for surface geochemical hand specimens taken. They are categorized into five different sample types, namely:

- **Rocks** (if from exposed rock units),
- **Laterites** (if from hard duricrust),
- **Soils** (if collected from soils),
- **Gravels** (if sampled from unconsolidated gravels) and
- **Anthills** (if sampled from anthills or termites mounds).

Sample description goes together with regolith mapping through which four primary regolith regimes are recognized. These regimes are namely **hardpan** (in situ or transported), **eluvium, colluvium and alluvium**.

7.4 Quality Assurance and Quality Control (QA/QC)

QA is a proactive approach to ensure that chemical analyses of rock and soil samples are correct and accurate. QA systems and procedures occur before a batch of samples is sent to the laboratory for analysis. Typically, QA involves the addition of "check" samples including:

- Blanks,
- Standard samples and
- Duplicates.

QC in contrast, is a reactive process of analyzing the data returned from the lab. This is crucial for determining the quality of data and for revealing any deviations from the norm.

Appropriate QA/QC of samples from both drilling and soil sampling is critical if results are to be trusted by targeting and resource estimation.

An independent QA/QC material used includes standards, blanks and duplicates. Certified reference materials (or standards) are used to check analytical accuracy. Blanks are used to check for contamination during the sample preparation phase. Duplicate samples are to check for analytical repeatability (precision) results of which are affected by both analytical precision and the natural grade distribution in the material sampled. With gold it is common that the latter can dominate any patterns observed.

All blank and standard failures are re-assayed at the cost of the laboratory; ten (10) samples are re-submitted, which include five below and five above the failed blank or standard.

Also, 10% of the total sample results assayed by SGS Siguiri laboratory are selected in each quarter and sent to SGS Ouagadougou laboratory for external control.

A random selection of QA/QC is done in the database and plotted using excel and macro software.

7.4.1 Blanks

A blank sample is added to the beginning of a sample batch. Blanks are used to determine whether a laboratory is clean or not. Busy laboratories are under constant time pressures and when there is a high throughput, mistakes and omissions become a real possibility, even with the best systems in place. It all comes down to human nature and the economics of running a laboratory. All too often, a technician may be under so much pressure that a crusher or ring mill is not cleaned properly before the next sample or batch of samples.

Crushing and grinding equipment is normally cleaned with what is commonly known as a ‘quartz rinse’, that is very clean quartz sand.

Washed river sand, is also commonly used as a blank for QA purposes. Again, it can end up as a component of concrete, unless carefully labeled.

A geologist can quickly pick up any contamination issues by plotting two different elements against each other. Blanks are made of local non-mineralized crushed granite rock with a weight of 1 kg.

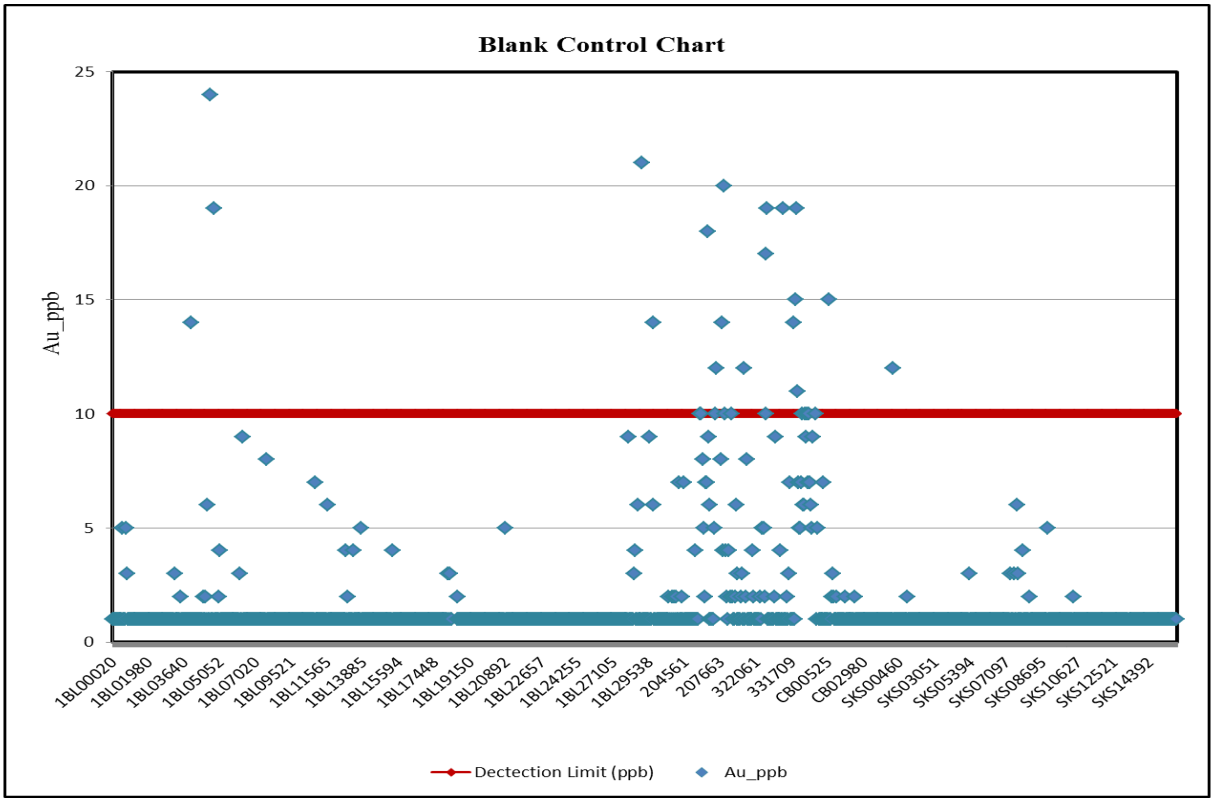

Figure 26: Blank material analysed by Aqua Regia for gold with 5ppb the expected value at a detection limit of 10 ppb (this study, 2014).

7.4.2 Standards

Standards or certified reference materials are added throughout batches to detect cross-contamination and sample switches. Standards are normally purchased from reputable suppliers. However their pre-packaged appearance is a dead giveaway to laboratories. In addition, because they usually come pre-prepared, they do not test the sample preparation stage for cleanliness. Laboratories can become familiar with which result is expected from a standard, even without any identification on the packet.

An alternative is to prepare in-house standards which look similar to regular samples. That way the laboratory has no idea that it is a standard and will therefore treat it like a normal sample. Unfortunately, there is a higher cost associated with doing this as in-house standards need to be assayed several times prior to their routine use, preferably at different laboratories, to obtain an average composition for the material.

A line-plot of assayed standards will instantly show any deviations, which can then be investigated to identify the cause of the discrepancy.

Base on the interpreted dataset, the graph below shows 97% accuracy within 1 standard deviation of the mean (see the ‘Summary statistics’ in **Figure 27** and **Figure 28**). The entire standard performed well.

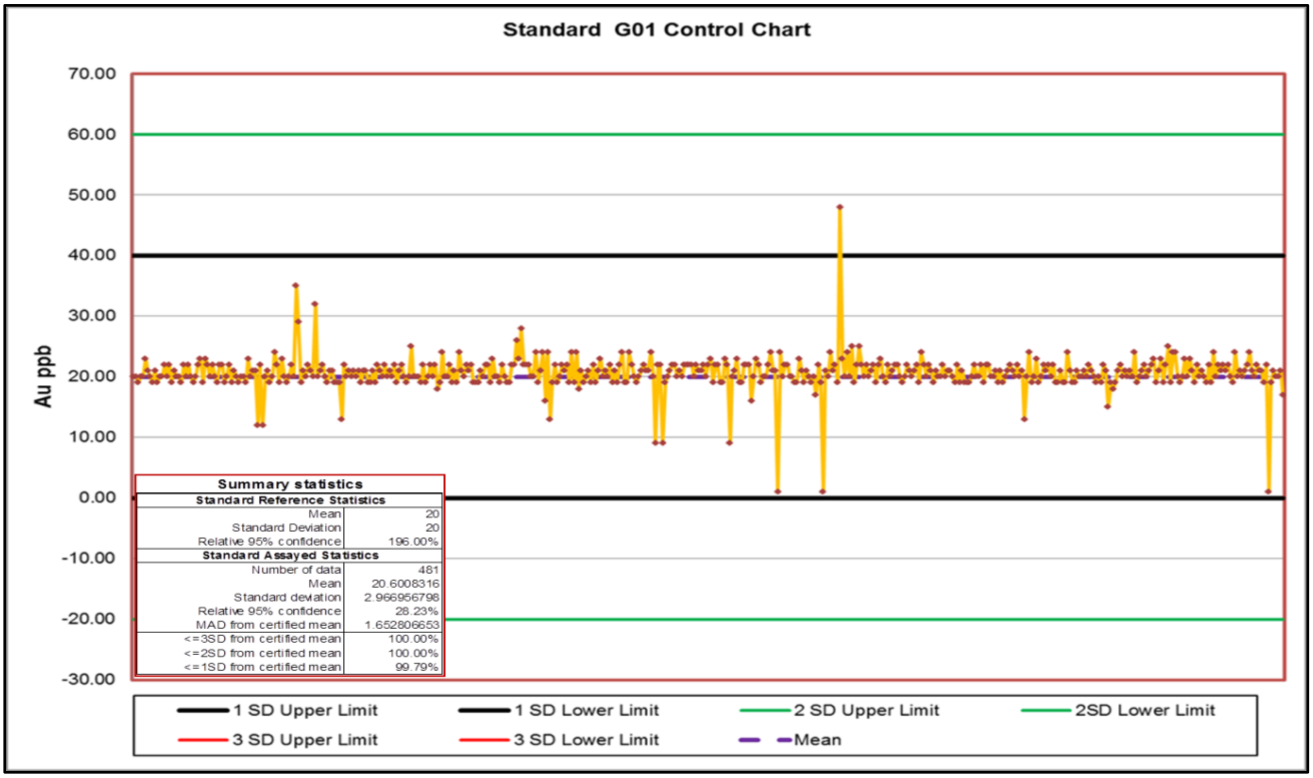

Figure 27: G01 CRMs results analysed by Aqua Regia for Gold (20ppb expected value) and are reported within ±3 SD (this study, 2014).

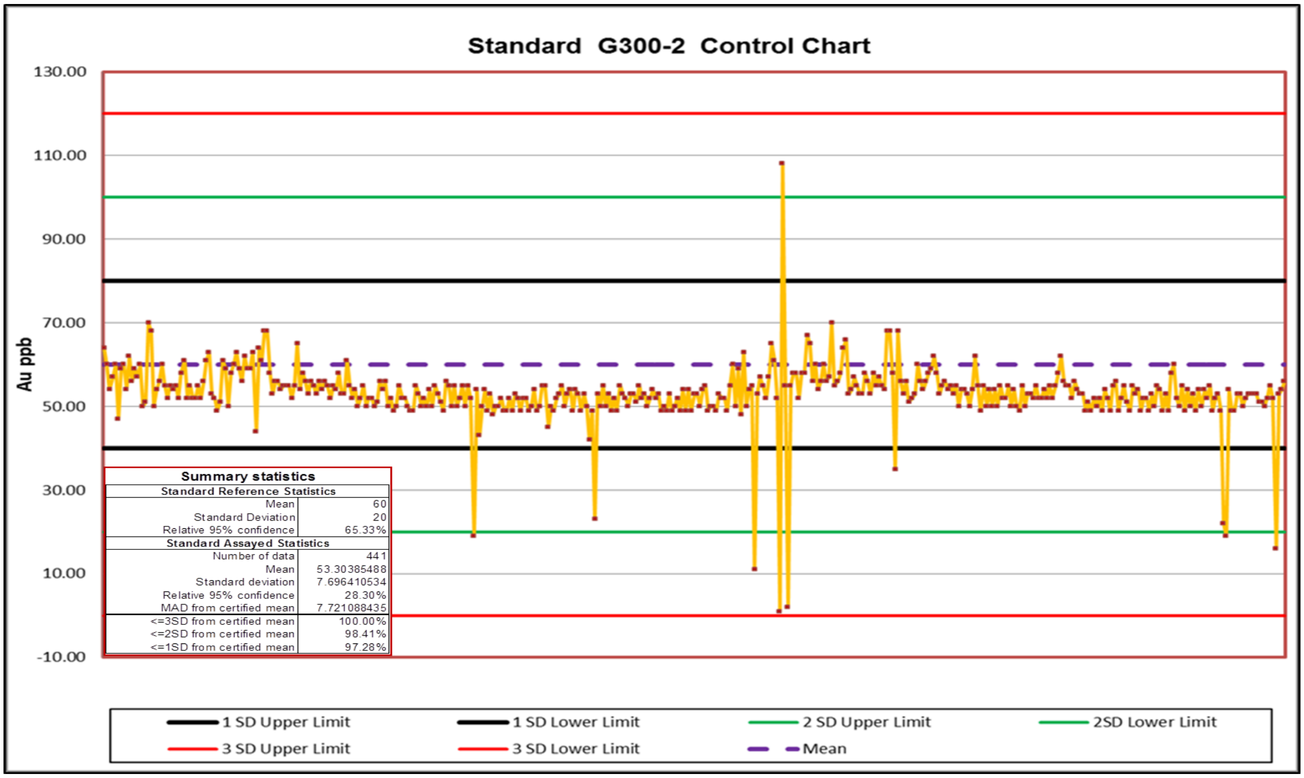

Figure 28: G300-2 CRM results analysed by Aqua Regia for gold (60ppb expected value) and are reported within ±3 SD (this study, 2014).

7.4.3 Duplicates

Duplicates are two identical samples submitted to the laboratory for analysis to detect sample switches and/or cross-contamination issues. They can be submitted proactively with the batch. Alternatively, the same sample can be re-submitted at a later stage to check if an unusually high result is valid or not.

The reactive approach is not the best approach, because unusually low results may be missed, potentially missing an important result.

Sample switching can sometimes occur at any stage during sample handling. Laboratories normally have in place systems which minimize the potential for this happening.

Coarse duplicates were taken by digging a second pit adjacent to the original sample pit and to the same depth and or digging one pit and split the sample in two. A total of 1469 duplicates were analysed for and found to have correlation coefficients equal to 0.140 for Au and cc=0.494 for As respectively. These are considered in the report and are plotted on the graph below.

Table 4: A summary of gold for duplicate samples taken.

	Original Au	Repeat Au	Units	Distribution	Original Au	Repeat Au	Units
Population	1468			25.0%	2.00	3.00	ppb
Minimum	1.00	1.00	ppb	50.0%	3.00	3.00	ppb
Maximum	5151.00	2253.00	ppb	75.0%	5.00	5.00	ppb
Mean	20.96	18.14	ppb	80.0%	6.00	6.00	ppb
Std Dev	150.78	84.48	ppb	90.0%	8.00	9.00	ppb
CV	7.19	4.66		97.5%	12.00	12.00	ppb
Correlation	0.179			99.9%	14.00	14.00	ppb

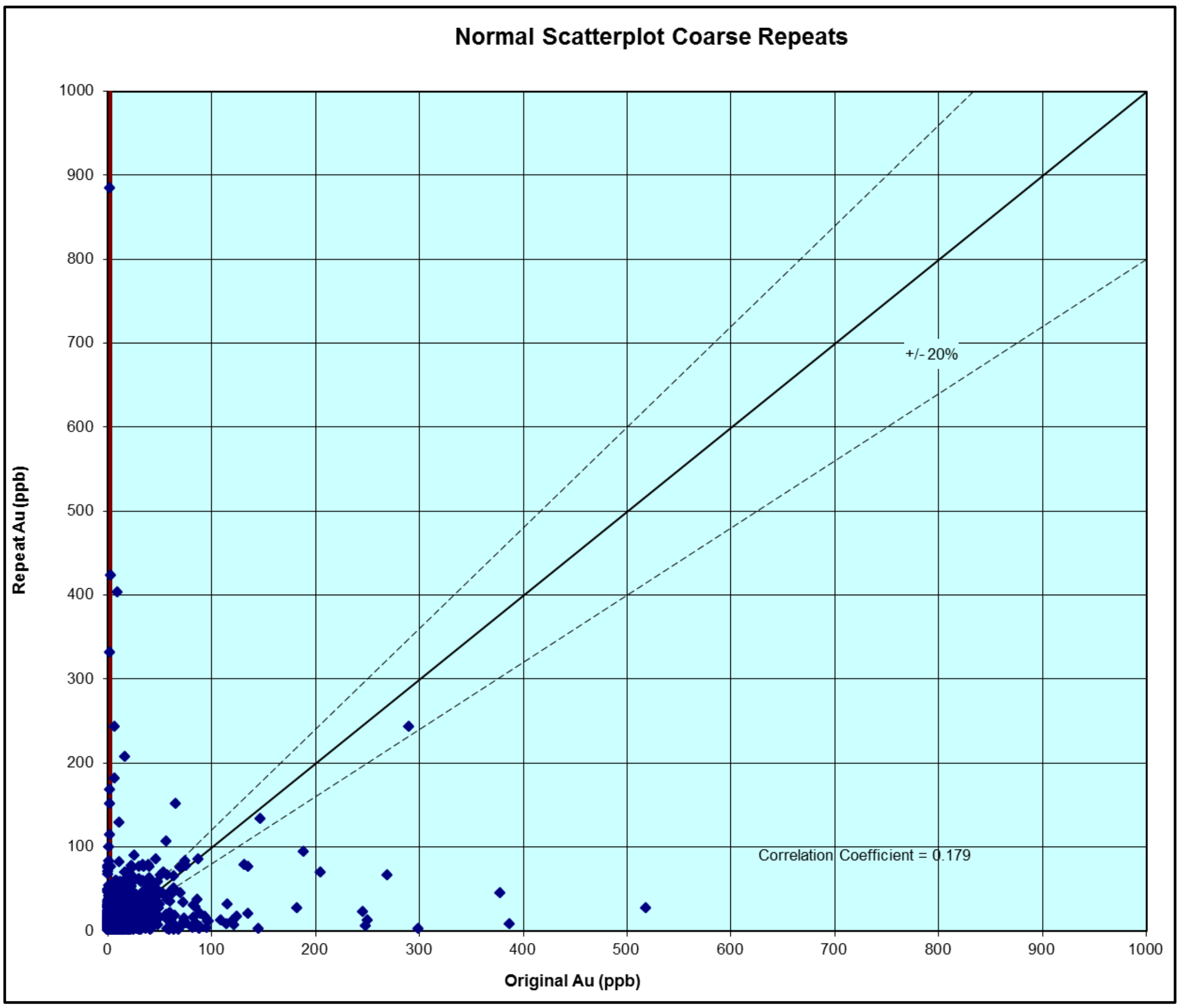

Figure 29: Graph showing the normal scatter plot for gold (this study, 2014).

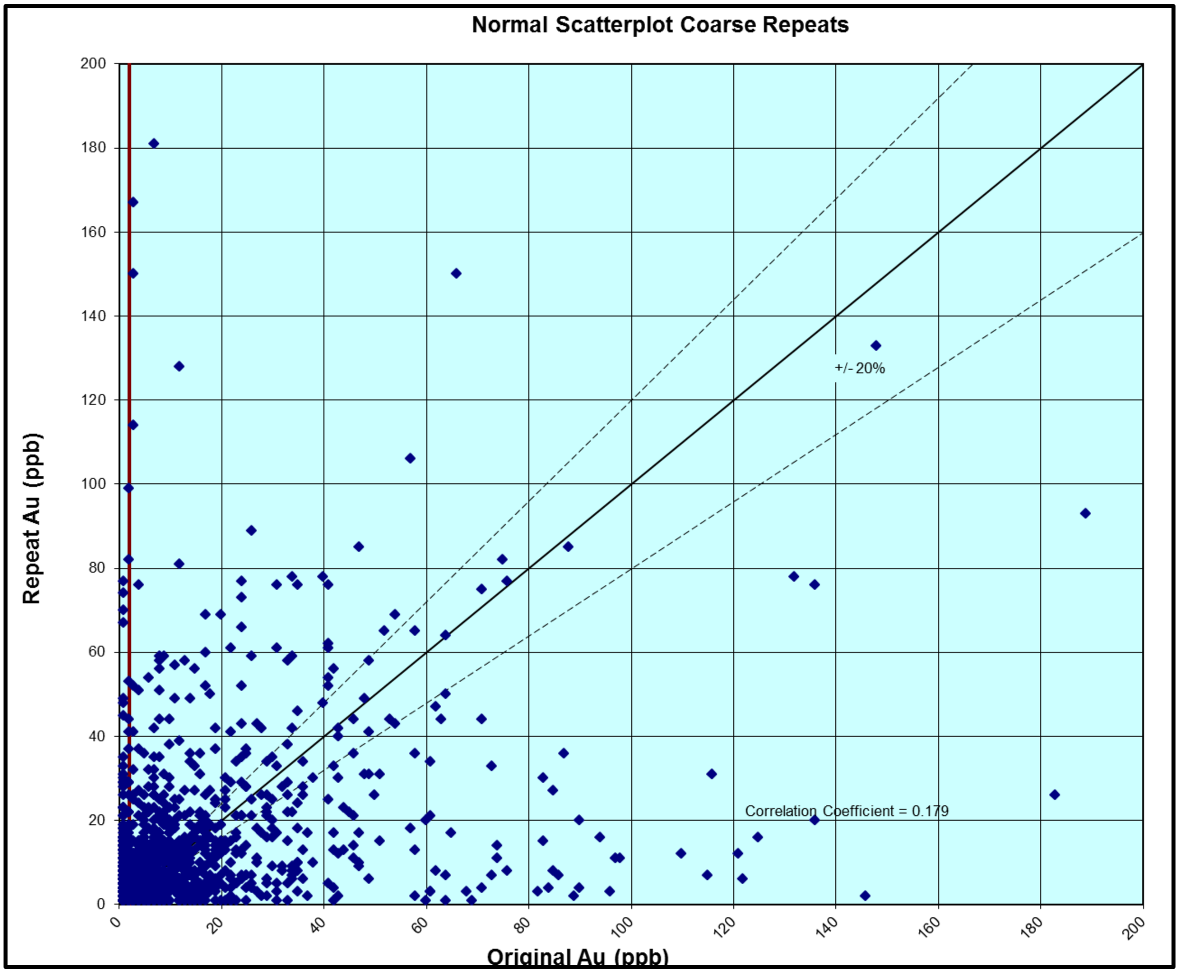

Figure 30: Graph showing the normal scatter plot for gold, the range scale is within 200ppb (this study, 2014).

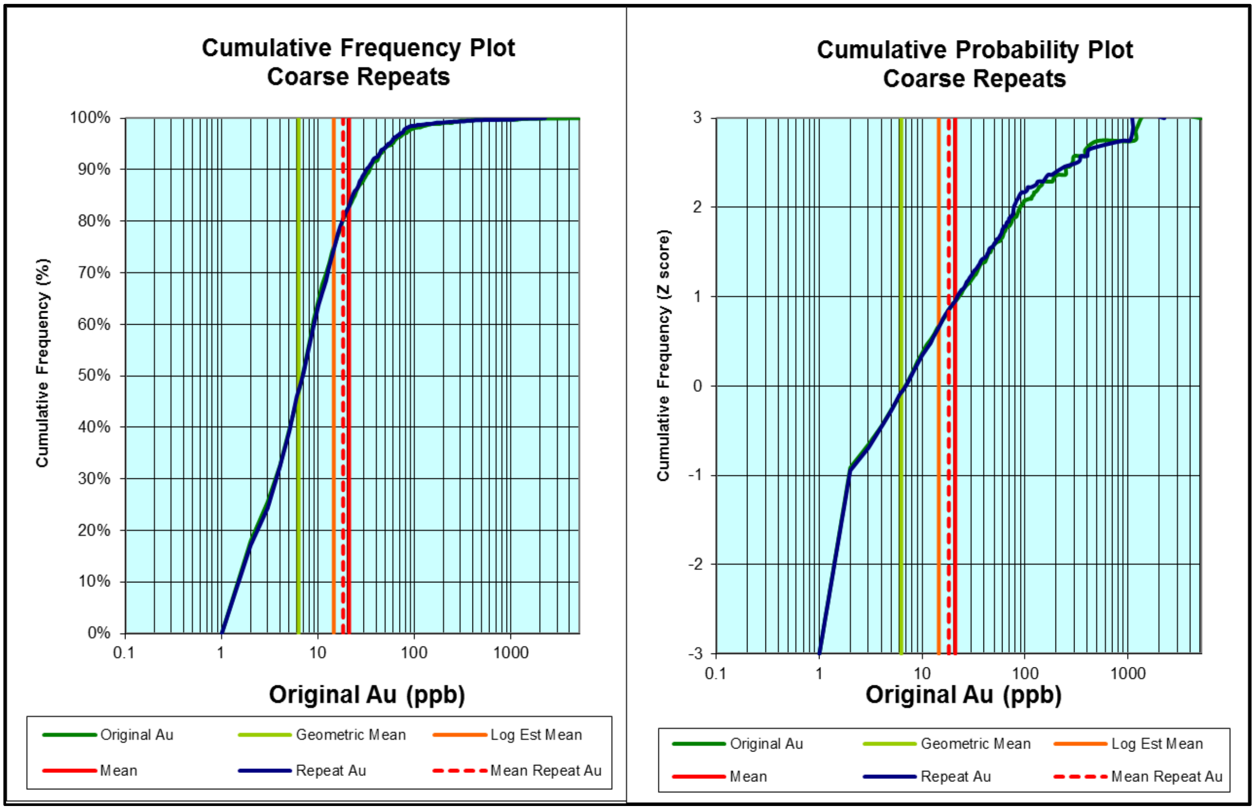

Figure 31: Graph showing the cumulative frequency and probability plot for gold (this study, 2014)

Table 5: Summary Table for plot of Arsenic for duplicate samples taken.

	Original As	Repeat As	Units	Distribution	Original As	Repeat As	Units
Population	1432			25.0%	10.00	10.00	ppm
Minimum	10.00	8.00	ppm	50.0%	10.00	10.00	ppm
Maximum	1086.00	1917.00	ppm	75.0%	10.00	10.00	ppm
Mean	46.40	49.20	ppm	80.0%	27.00	27.00	ppm
Std Dev	69.92	87.27	ppm	90.0%	36.60	36.00	ppm
CV	1.51	1.77		97.5%	49.00	49.00	ppm
Correlation	0.864			99.9%	56.25	57.00	ppm

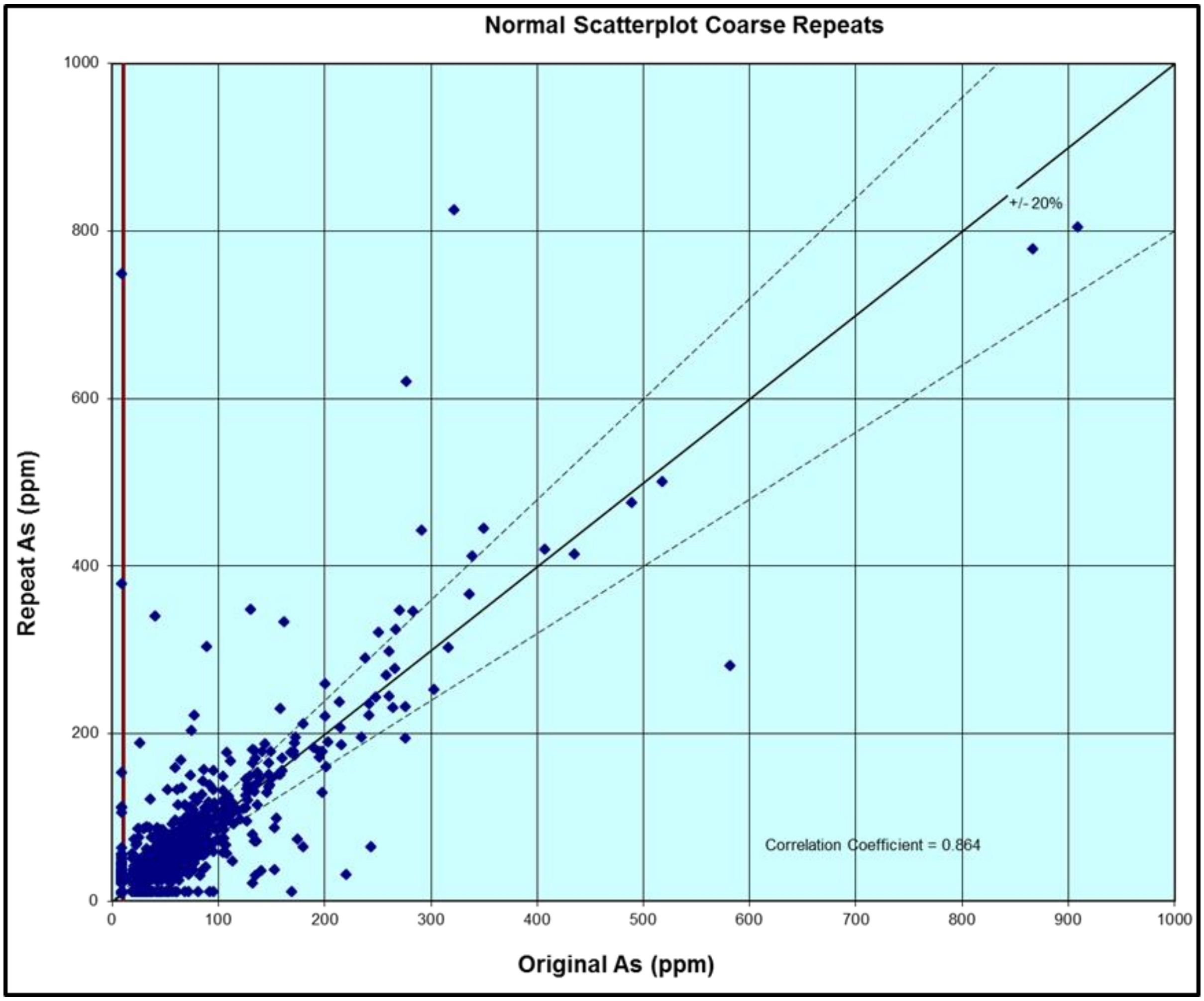

Figure 32: Graph showing normal scatter plot for arsenic (this study, 2014).

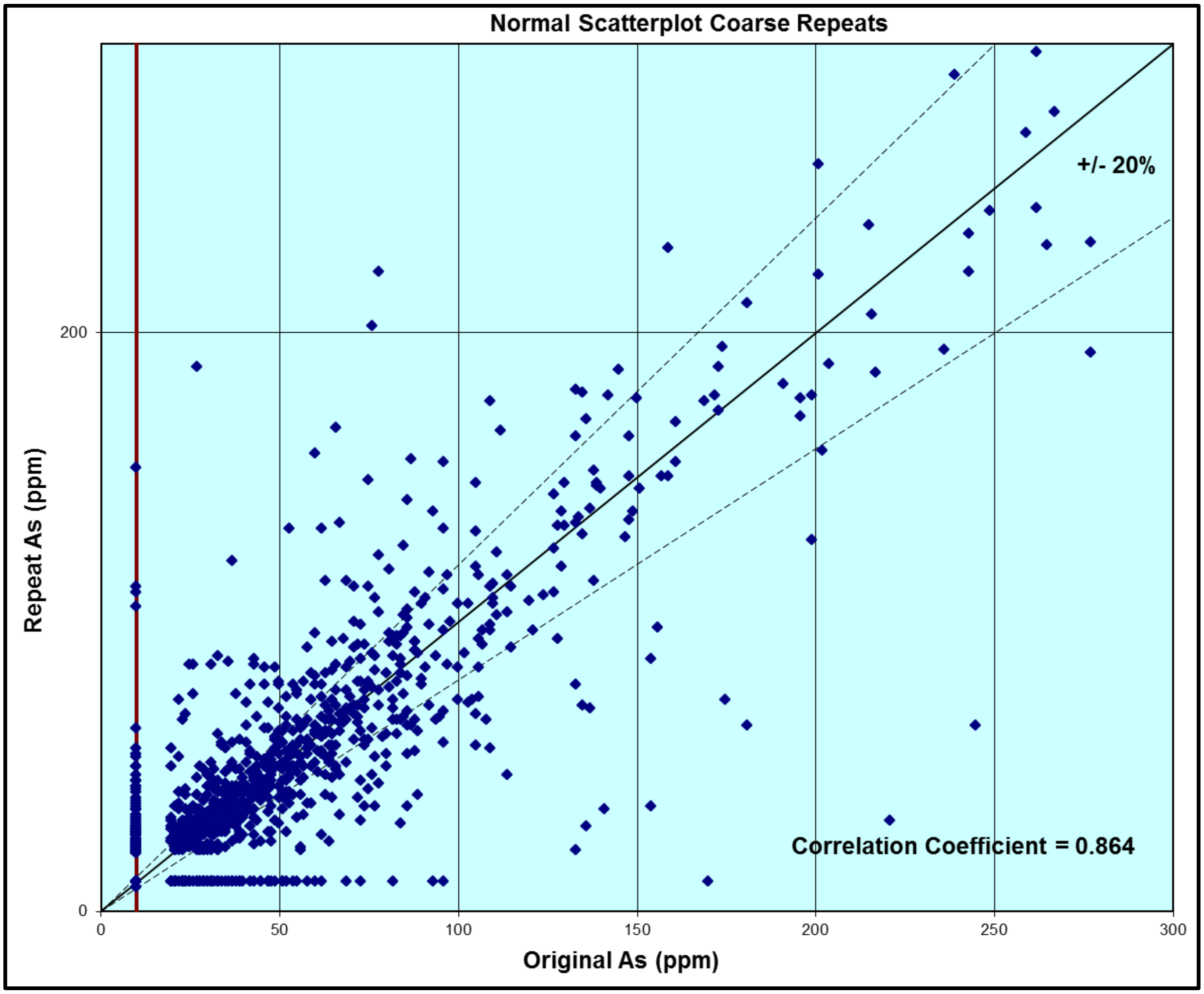

Figure 33: Graph showing normal scatter plot for arsenic the range scale is within 300ppm (this study, 2014).

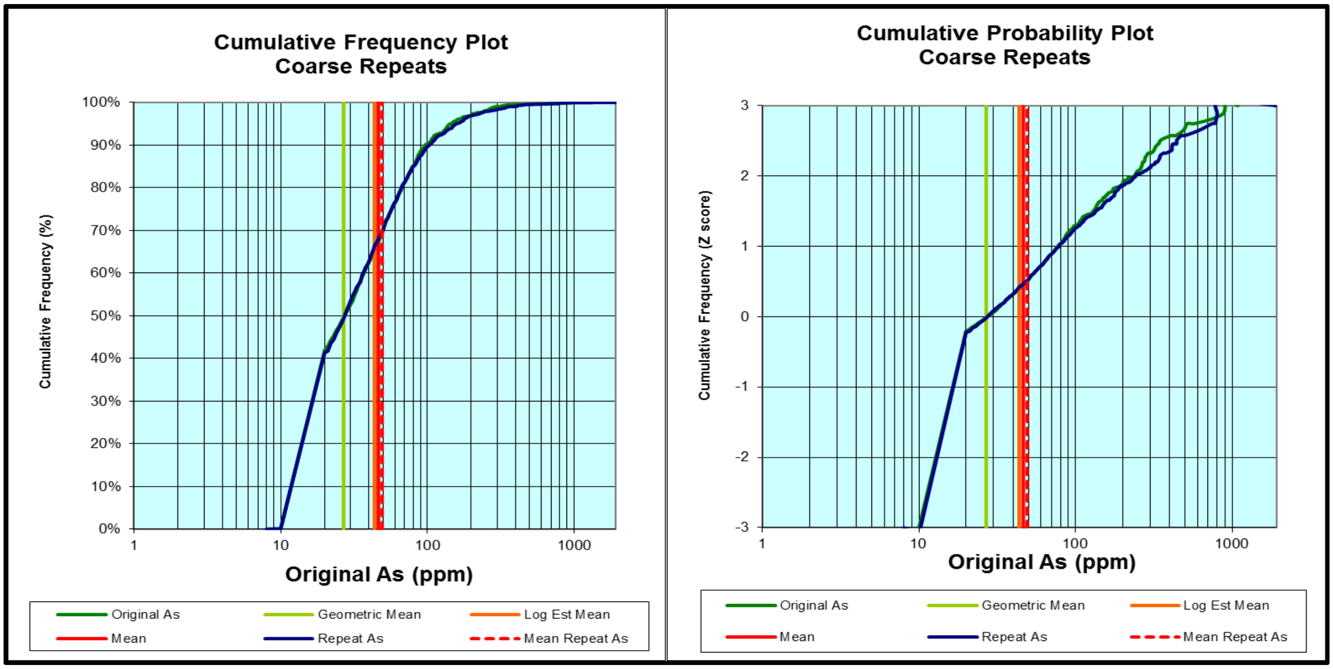

Figure 34: Graph showing the cumulative frequency and probability plot for arsenic (this study, 2014).

Chapter 8 : Data Processing and Interpretation in selected targets

8.1 Background

To process and interpret any data set, some of the concepts, rules, procedures and outline need to setup and understood that will help to:

- Organize numerical information in the form of Tables, graphs, and charts;
- Understand statistical techniques underlying decisions that affect our lives and well-being and to
- Make informed decisions

The data interpretation is described in the following steps for each selected target:

- Basic Statistics
- Data Management
- Anomaly threshold definition
- Multivariate data correlation and ratios
- Plotting

8.2 Basic Statistics

Basic statistic is based on geostatistics that considers the measures of central tendency such as ***Mean***, ***Median*** and ***Mode*** and the measures of spread such as ***Range***, V***ariance***, S***tandard Deviation***, ***Percentile*** and ***Coefficient of Variance*** (see the following two Figures below).

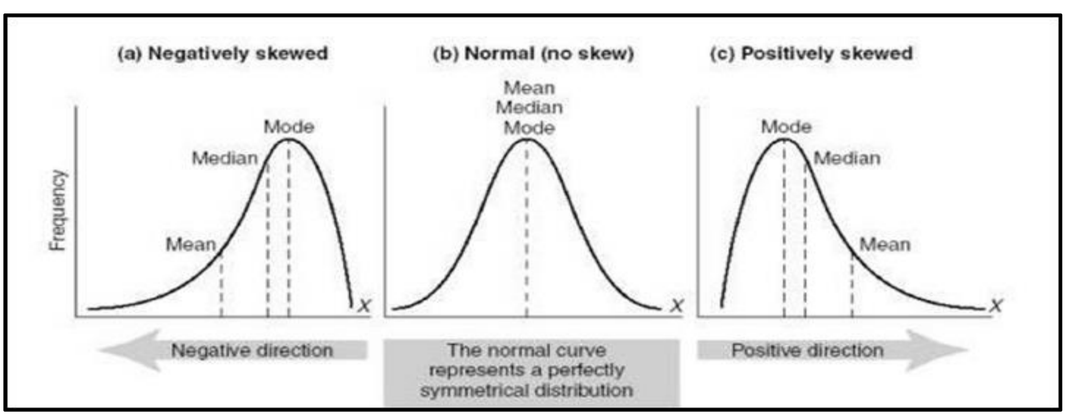

Figure 35: Measure of central tendency (Rhodes 2013, Soil geochemistry lecture).

The aim of the statistical analysis of this study is to interpret each target based on statistic such as ***descriptive statistics***, ***histogram***, ***rank and percentile*** and ***log probability***.

Table 6: Summary Table of Au_ (ppb) and As_ (ppm) content with the correlation coefficient of each target (Present study conducted during 2014)

Targeted Area Name	Au (ppb)		As (ppm)		Correlation coefficient of Au	Correlation coefficient of As
	Min	**Max**	**Min**	**Max**		
Balato	1	45080	10	13690	0.14	0.35
Kourouda SE	1	2592	10	316	0.26	**0.96**
Kourouda SW	1	88000	10	1410	0.86	0.99
Niono	1	2066	10	241	0.88	0.95
Seguelen	1	13400	10	14150	0.84	0.91
Silakoro	1	3500	10	411	0.84	0.95

8.3 Data Management

All Siguiri data are monitored and controlled by database software such as the previously used Maxwell system and now recently migrated to the Century system. This system can measure the data reliability, integrity and usability. Using database software can help people to easily process the data, talk a common language, and makes the data transparent and auditable. More advanced filters (SQL) are available. They enable efficient data capture, validation, import and export of quality data and assist with the plotting of the QAQC charts.

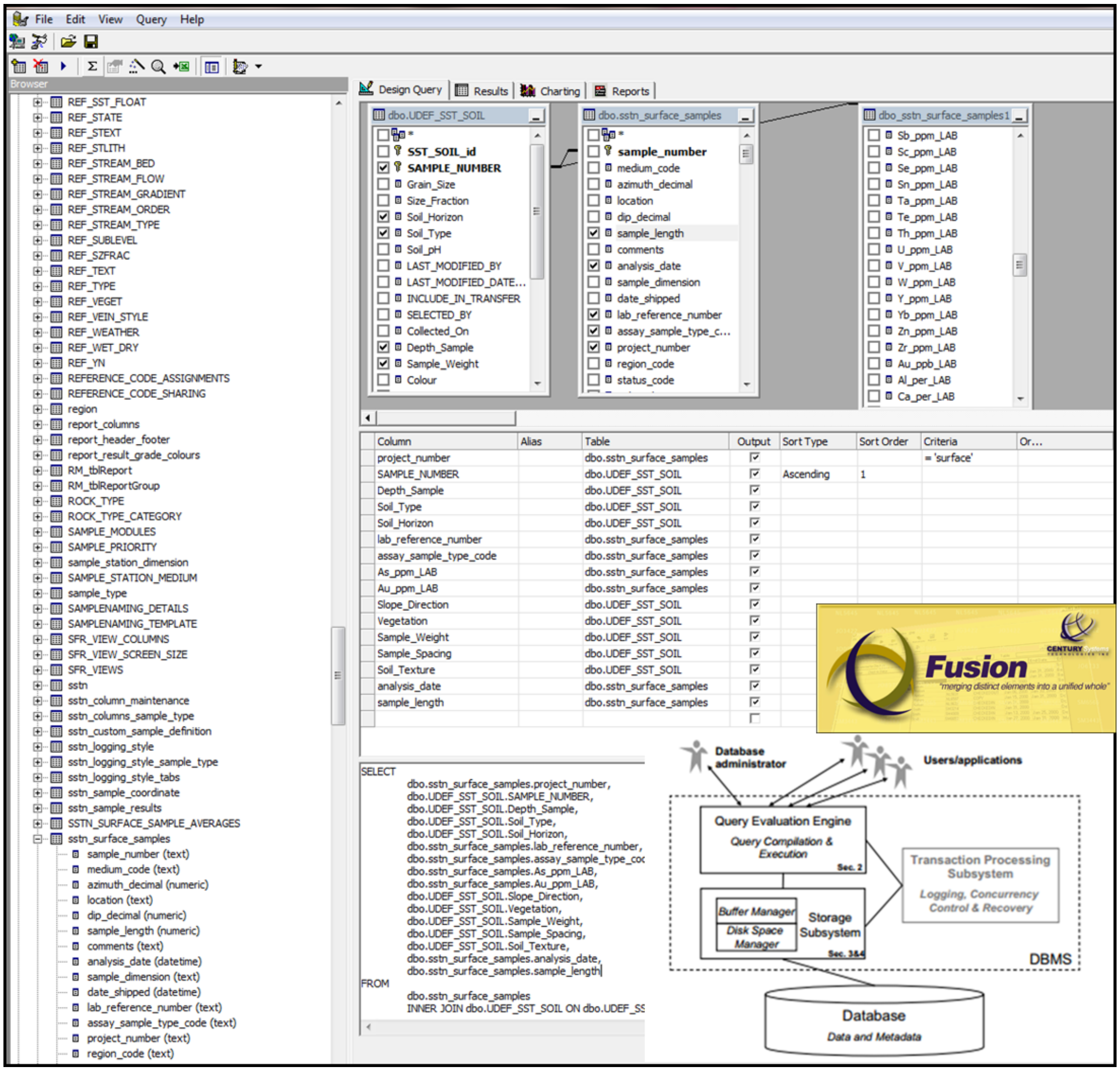

Figure 36: Schema showing the fusion data structure with query builders (Century systems).

8.4 Anomaly threshold definition

The background values of the rock types are determined and standardised as the standard deviation, histogram, standard deviation+mean and average (std+hist) value for both gold and arsenic, Both element datasets, in all the targets, have positively skewed histograms and are reported in the target description, as recommended by Hawkes and Webb (1962). The median and average element values are compared with the element crustal abundances (Levinson, 1973). Concentrations above the median are regarded as enriched or elevated, especially if supported by the underlying geology.

The anomalous threshold definition defines as first order anomaly relative to the primary environment which is absolute anomalism or economic mineralisation.

The second order anomaly is defined relative to the secondary environment which is absolute anomalism or relative anomalism. The different orders of anomalism are defined in order to prioritise the follow-up target.

The anomalous values which are greater than the mean + 1*Std are defined as reflecting the anomalous bedrock and the underlying geology (Hawkes and Webb, 1962, see Table below).

Table 7: Table summarizing anomalous threshold values for Au and As.

					Anomalies values				
Targeted Name	Elements	Mean	Median	Standard Deviation	Crustal Levels (Levison 1974)	Histogram (20 bins)	Anomalies (1xSTD +	Anomalies (2xSTD +	Ave (STD + Hist)
Balato	Au_ppb	56.79	11.00	879.88	5.00	550.00	936.67	1816.55	714.94
	As_ppm	69.49	44.00	223.93	15.00	450.00	293.42	517.35	336.97
Kourouda SE	Au_ppb	20.87	8.00	92.46	5.00	150.00	113.33	205.79	121.23
	As_ppm	40.31	36.00	32.13	15.00	130.00	72.44	104.57	81.07
Kourouda SW	Au_ppb	36.56	5.00	1252.62	5.00	325.00	1289.18	2541.80	788.81
	As_ppm	59.80	35.00	90.56	15.00	270.00	150.36	240.92	180.28
Niono	Au_ppb	18.84	7.00	93.02	5.00	200.00	111.86	204.88	146.51
	As_ppm	20.80	10.00	23.33	15.00	150.00	44.13	67.46	86.67
Seguelen	Au_ppb	86.26	10.00	493.93	5.00	1225.00	580.19	1074.12	859.47
	As_ppm	99.66	55.00	346.16	15.00	225.00	445.82	791.98	285.58
Silakoro	Au_ppb	25.70	5.00	166.56	5.00	210.00	192.26	358.82	188.28
	As_ppm	26.07	10.00	28.94	15.00	100.00	55.01	83.95	64.47

8.5 Selected target Study

8.5.1 Balato target

8.5.1.1 Background

The Balato target occurs along a north-westerly corridor that connects both the Eureka North and the Kintinian pits. The corridor is defined in the MIDAS helicopter magnetic and radiometric survey, and the SPECTREM time constant grid. The target is sited at the focal junction between the north-west structural corridor and the north-south structural trend with anomalous gold in soil geochemistry. This target was considered of high priority and drilling was recommended. The target was later tested through air core drilling at the reconnaissance stage 400*100 m and no economic intersection was delineated. There is no ground geophysics done over the target.

8.5.1.2 Surface soil

A total of 5,302 soil samples were collected and assayed for gold and arsenic. Based on the assay results after data validation, a descriptive statistic study (**Table 8**) is presented for the area. A histogram showing the different populations and the probability showing the variation of the trend line with the correlation of coefficient for Au and As plot are presented on the graphs **Figure 37** and **Figure 38**.

As show in the histogram plot two populations can be defined. This is the same for the probability plot (**Figure 37**).

Table 8: Summary of the descriptive statistics of Au and As for Balato target (This study, 2014).

	Au (ppb)	**As (ppm)**
Mean	56.79	69.49
Standard Error	12.08	3.21
Median	11.00	44.00
Mode	1.00	10.00
Standard Deviation	879.88	223.93
Sample Variance	774195.70	50145.28
Kurtosis	2357.43	2833.30
Skewness	47.48	47.86
Range	45079.00	13680.00
Minimum	1.00	10.00
Maximum	45080.00	13690.00
Sum	301127.00	338019.00
Count	5302.00	4864.00
Largest(1)	45080.00	13690.00
Smallest(1)	1.00	10.00
Confidence Level(95.0%)	23.69	6.29

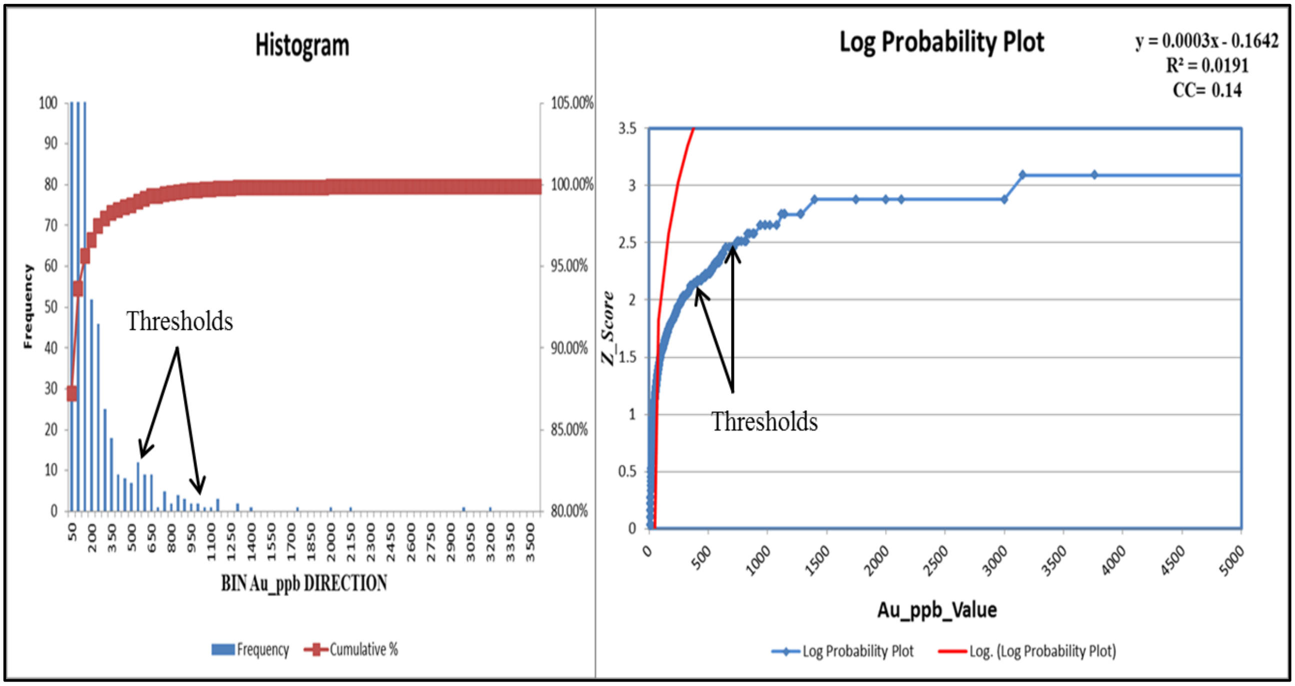

Figure 37: Two graphs showing the histogram and log probability plot (Z_Score) of Au_ppb highlighting the anomalous threshold values of Balato target respectively.

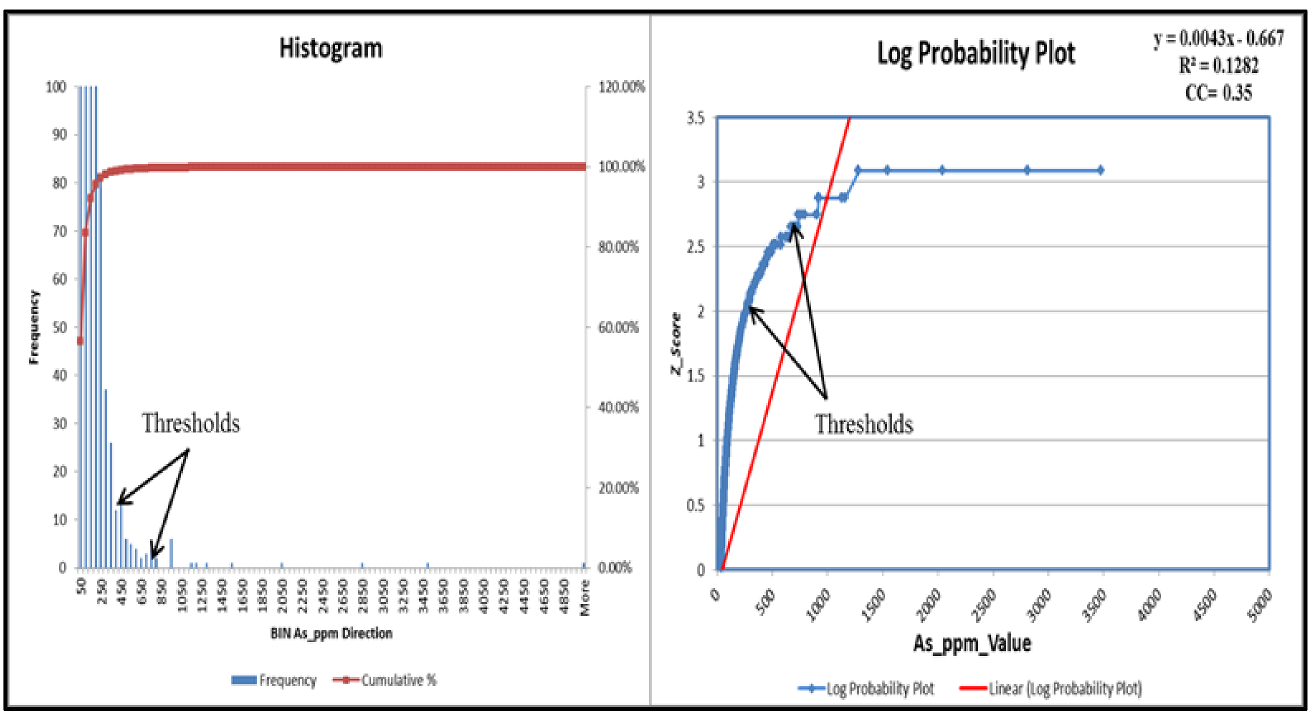

Figure 38: Two graphs showing the histogram and log probability plot (Z_Score) of As_ppb highlighting the anomalous threshold values of Balato target respectively.

8.5.1.3 Regoliths

The Balato targets have a shallow weathering profile with thin residual cover at high elevation. Most of the area is covered by duricrust, gravel, saprolitic soil at the edge of the scarp and soil and low elevation and along the rivers. Outcropping meta-sediments with in-situ quartz veins suggest a high potential for mineralization, especially at the North 1 and NE targets. Prominent veins follow the main mineralised set at Block1 as they dip towards the south-east and north-west. Bedding dips coherently towards the west making the (surficial) area structurally monotonous.

Artisanal local mining activities are being involved along the Koron River in the southwest and others rivers within the area. Shallow metal detector, mining activities occur within transported gravels overlying duricrust in certain area of the target.

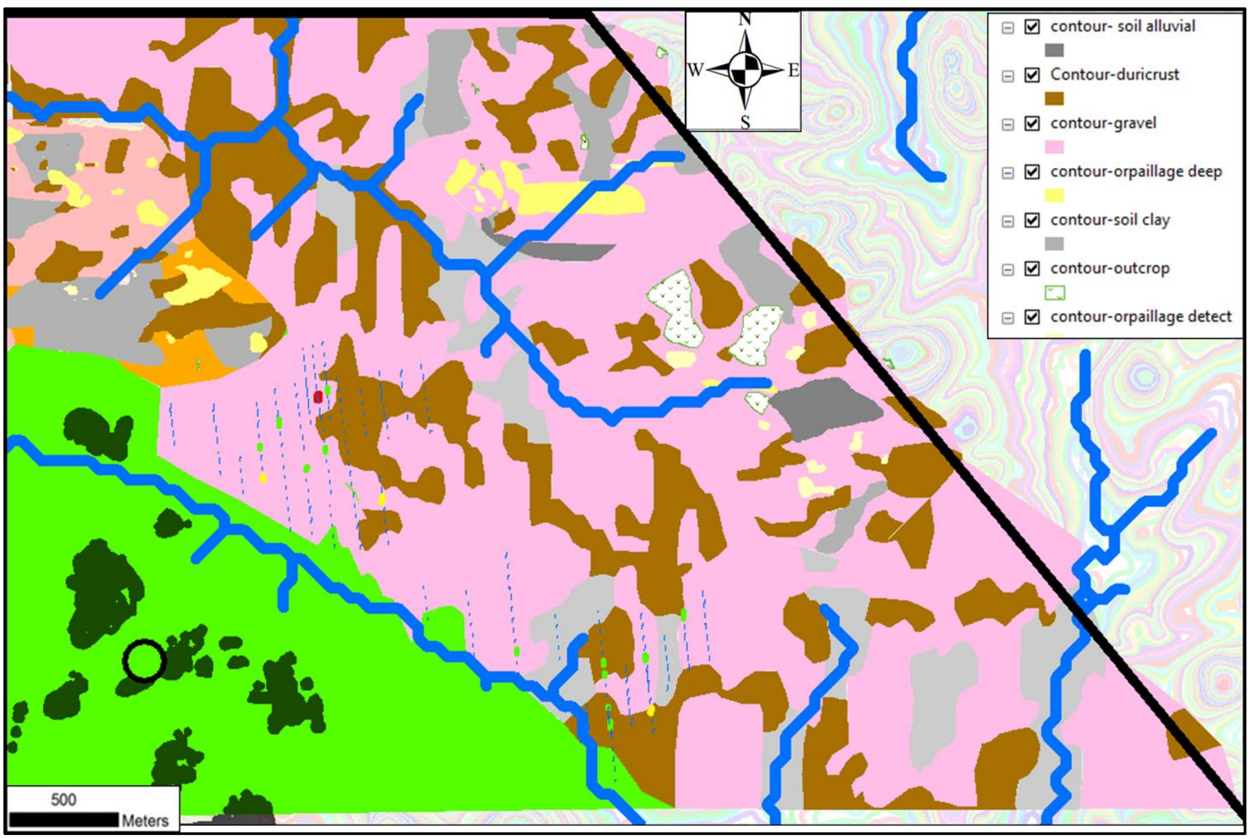

Figure 39: Balato regolith map the green is showing the mining area with the pit shell in black (this study, 20140.

8.5.1.4 Drilling

Some air core drilling was planned and drilled at 400 x 100 m grid spacing over the area to test the defined target. Some of the drill holes returned good results and an infill drilling project at 200 x 100 m grid spacing was planned around the good intercepts. Unfortunately the latter results obtained were insignificant and there is no economic mineralisation defined. A second diamond drill hole was subsequently drilled to support the geological and structure interpretation.

8.5.2 Kourouda South East Target

8.5.2.1 Background

The target area have been identified based on geophysics, large soil geochemistry anomaly covering an area of roughly 8km² and the conceptual model following structural studies carried out in the pits by members of the Australian based Centre for Exploration Targeting (CET Annual in-house report, 2011).

The target seems to be much related to the north-south trending F2 fold axis, north-south trending ore shoots are deflected between Sintroko and Sintroko pushback 2 (Flexure1). The deflection fits to the irregular elliptical shape of the geophysical anomaly observed in the AEM images. The anomaly could correspond to the lithological heterogeneity in the meta-sediments.

8.5.2.2 Surface Soil

A total of 2,126 soil samples were collected and assayed for gold and arsenic. Based on the validated assays results, descriptive statistics shown in **Table 9** is calculated for the area. A histogram showing the different populations and a log probability plot is shown in the graphs below.

Table 9: Summary Table showing the descriptive statistics for the Kourouda South East target.

	Au (ppb)	As (ppm)
Mean	20.87	40.31
Standard Error	2.10	0.73
Median	8.00	36.00
Mode	1.00	10.00
Standard Deviation	92.46	32.13
Sample Variance	8548.09	1032.58
Kurtosis	417.92	9.72
Skewness	18.47	2.06
Range	2591.00	306.00
Minimum	1.00	10.00
Maximum	2592.00	316.00
Sum	40328.00	77190.00
Count	1932.00	1915.00
Largest(1)	2592.00	316.00
Smallest(1)	1.00	10.00
Confidence Level(95.0%)	4.13	1.44

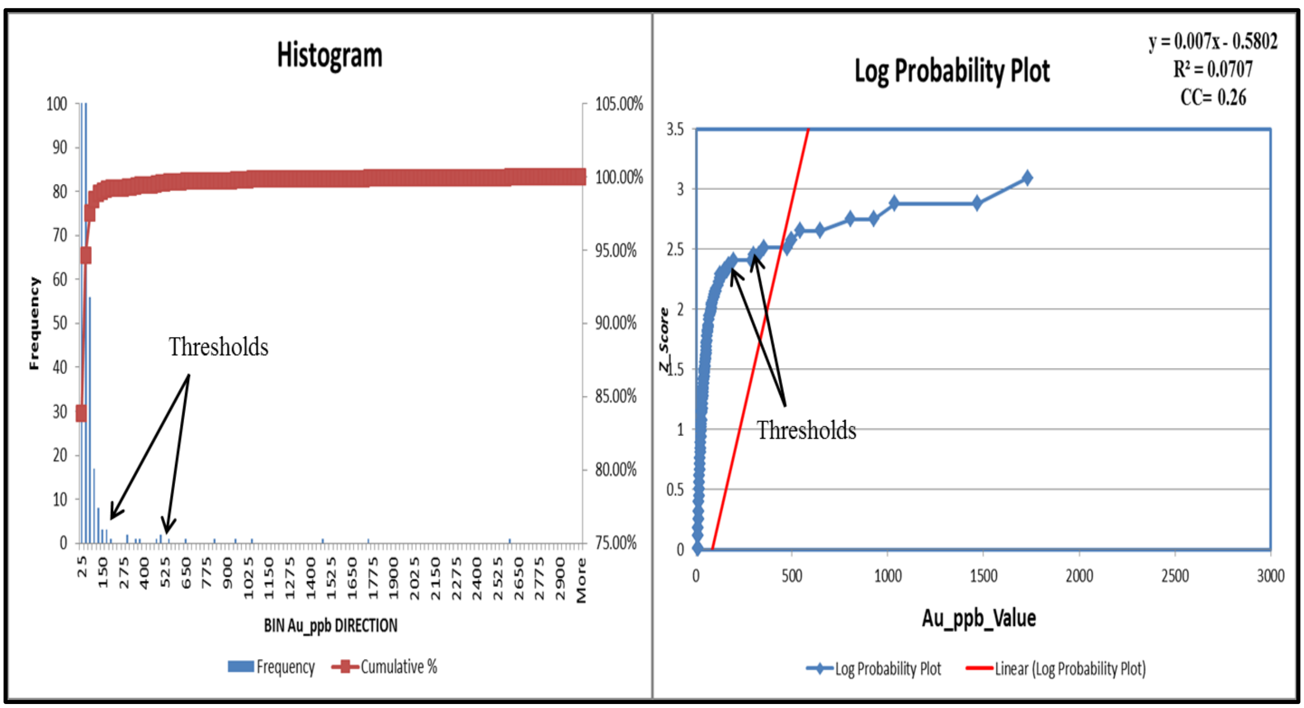

Figure 40: Graph showing the histogram and log probability plot (Z_Score) of Au_ppb highlighting the anomalous threshold value of Kourouda South East target.

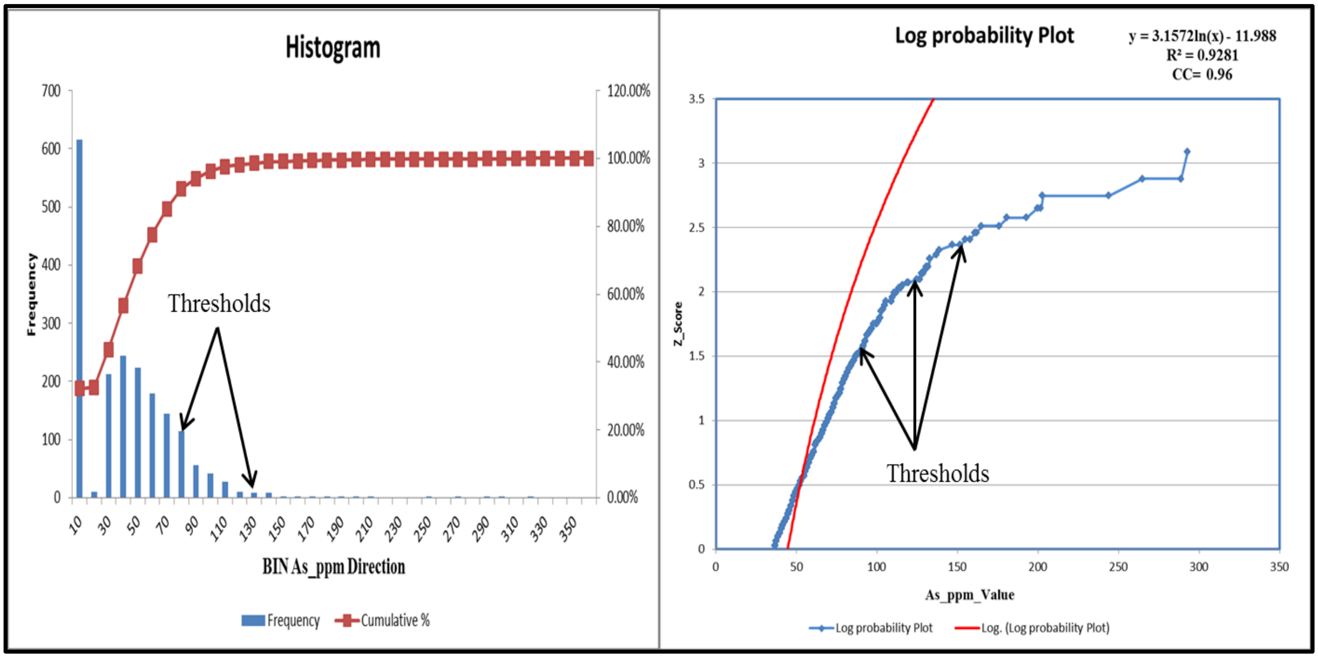

Figure 41: Graph showing the histogram and log probability plot (Z_Score) of As_ppb highlighted the anomalous threshold value of Kourouda South East target.

8.5.2.3 Regoliths

The Kourouda South East target is situated on a lower plateau incised into flood plain. Most of the area is covered by duricrust at high elevation and middle plateau, gravel, and soil (sand and clays) at low elevation and along the rivers.

Artisanal local mining activities is been involved in shallow deep dig holes along the north-south river trends. Recently shallow metal detector activities were used to test the gravels overlying on the duricrust in certain area of the target.

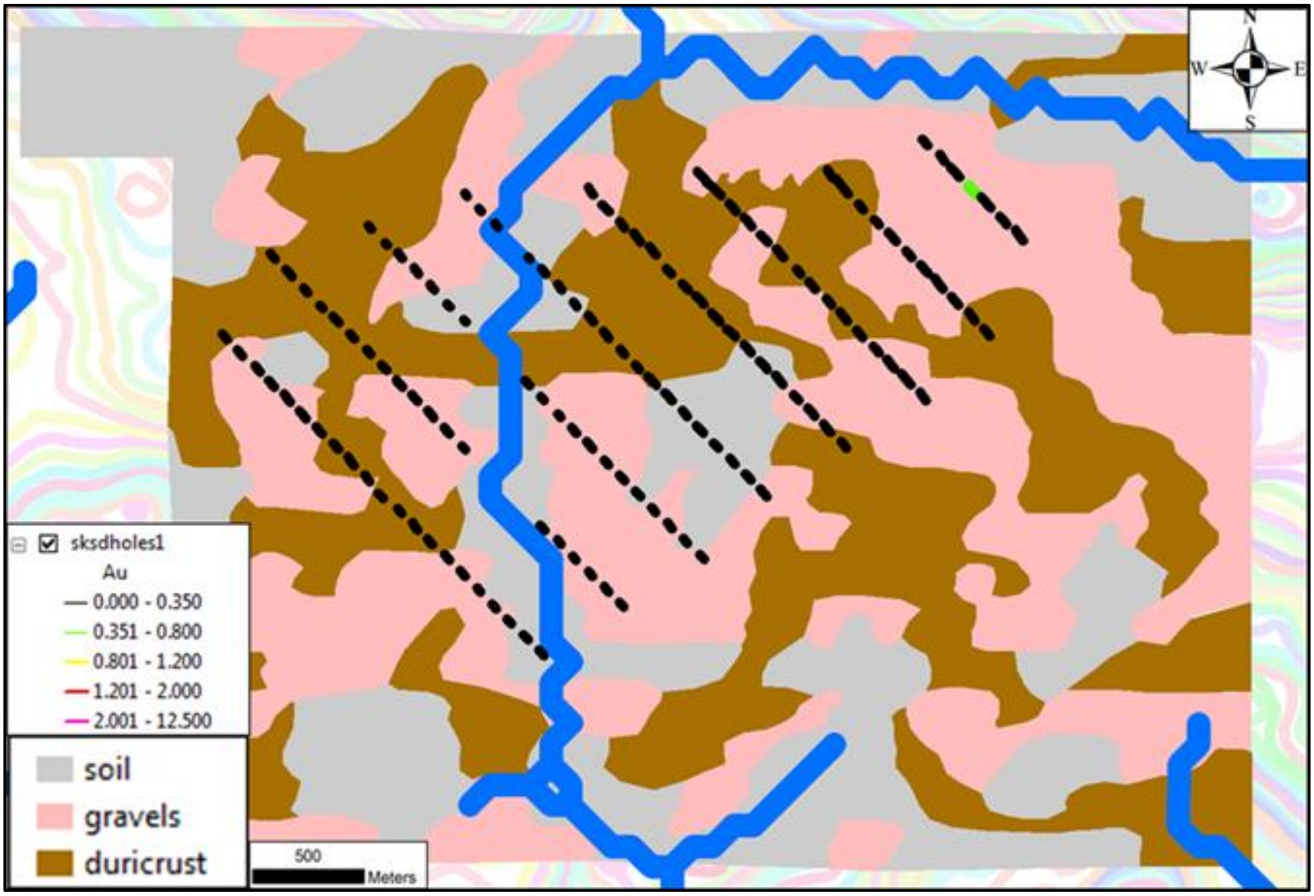

Figure 42: Kourouda south east regolith map with the drill holes in black dot (this study, 2014).

8.5.2.4 Drilling

The target has been tested by air core drilling and only one hole comes with 3 m @ 2g/t Au. This can be justifying by the result poorly obtained within the AngloGold Ashanti geophysical study and there is no ground geophysics carried out over the target.

8.5.3 Kourouda South West Target

8.5.3.1 Background

Target areas were identified based on geophysical, geochemical interpretation and a conceptual model following structural studies carried out in the pits by members of the Australian-based Centre for Exploration Targeting (CET Annual in-house report, 2011). It's also based on John Bell (AngloGold Ashanti Senior regional geophysicist) on geophysical interpretations (IP, Resistivity and Gravity) from a survey conducted in the area.

8.5.3.2 Surface Soil

A total of 5,458 soil samples were collected and assayed for gold and arsenic. Base on the assays results after data validation, a descriptive statistics study (Table 10) is done for this area. A histogram showing the different population and a probability plots showing the variation in the trend line are presented the graphs below.

Table 10: Summary of the descriptive statistics of Kourouda South West target

	Au (ppb)	As (ppm)
Mean	36.56	59.80
Standard Error	16.96	1.26
Median	5.00	35.00
Mode	1.00	10.00
Standard Deviation	1252.62	90.56
Sample Variance	1569046.99	8201.22
Kurtosis	4505.57	42.60
Skewness	65.58	5.13
Range	87999.00	1400.00
Minimum	1.00	10.00
Maximum	88000.00	1410.00
Sum	199565.00	311029.00
Count	5458.00	5201.00
Largest(1)	88000.00	1410.00
Smallest(1)	1.00	10.00
Confidence Level(95.0%)	33.24	2.46

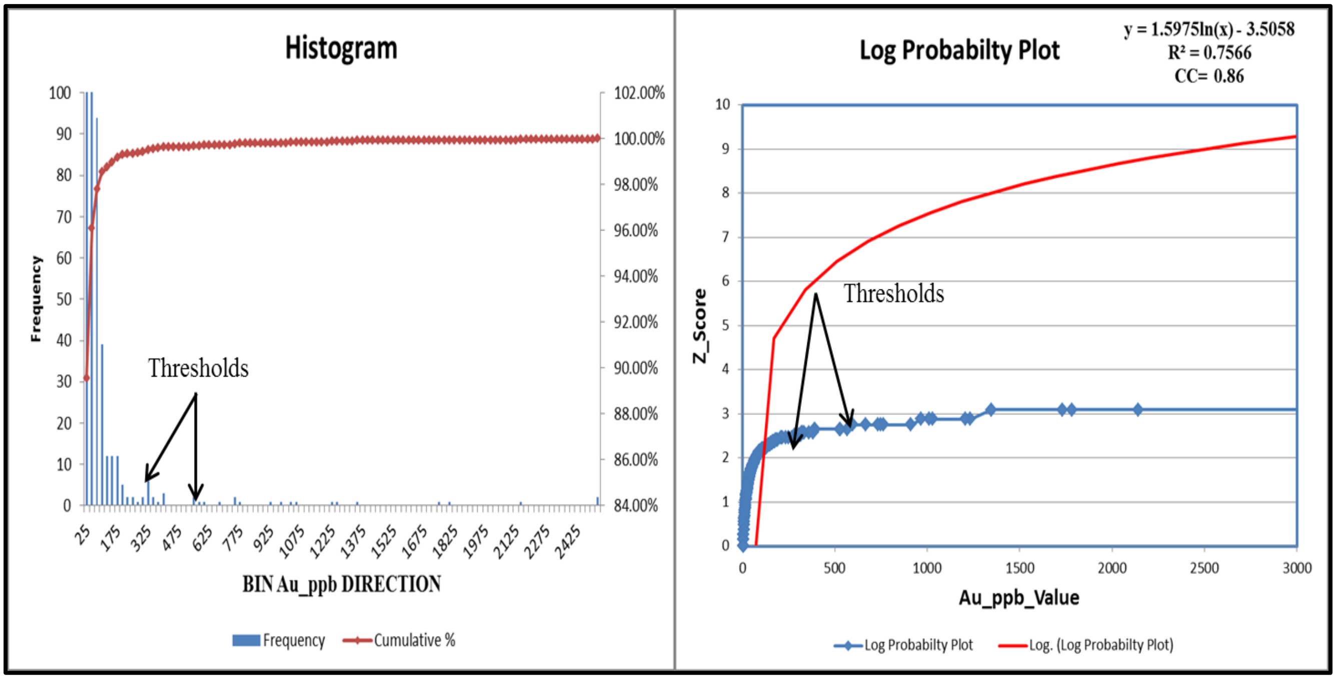

Figure 43: Graph showing the histogram and log probability plot (Z_Score) of Au_ppb highlighted the anomalous threshold value of Kourouda South West target.

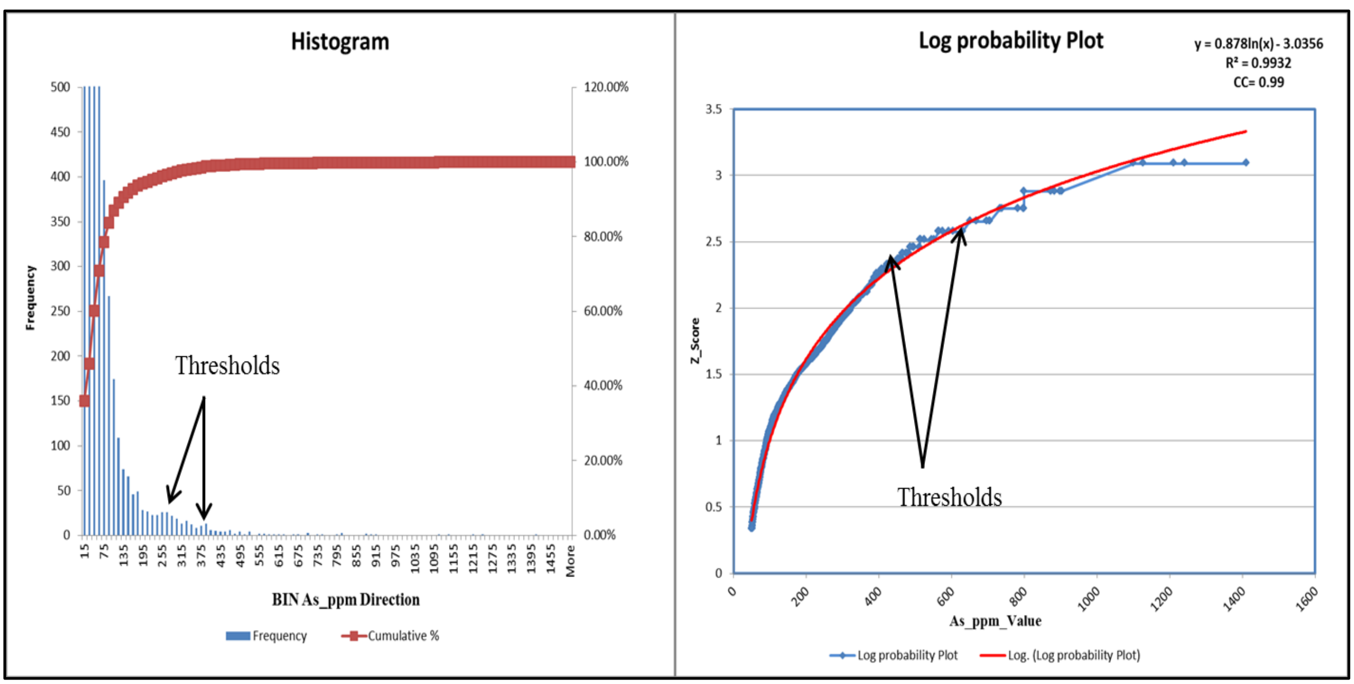

Figure 44: Graph showing the histogram and log probability plot (Z_Score) of As_ppb highlighted the anomalous threshold value of Kourouda South West target.

8.5.3.3 Regoliths

The majority of the target is covered by a topographic high duricrust with duricrust-derived gravel scree strewn along slopes. These gravels are also developed as islands on top of the duricrust layer. The duricrust gravels and duricrust benches developed towards the NE and SW at higher elevations and the duricrust are also directly in contact with saprolitic soils and clays.

The target is cut by a north-west/south-east directed river exposing residual soils and clays with minor alluvial sands. Angular saprolitic scree/gravel was observed towards the south of the target, possibly indicating a residual origin. The thick transported regolith may mask the Au geochemical signals.

Shallow, metal detector, mining activities occur within transported gravels overlying duricrust just outside the SE boundary of the target. Large areas to the north-east of the target are actively being mined. Miners primarily focus on thin gravels covering the duricrust. South of the target deep holes are burrowed into saprolite along the banks of a stream. It is unsure whether alluvial or in-situ gold was mined, but quartz vein chips are observed in washed material heaps found close to the burrowed holes.

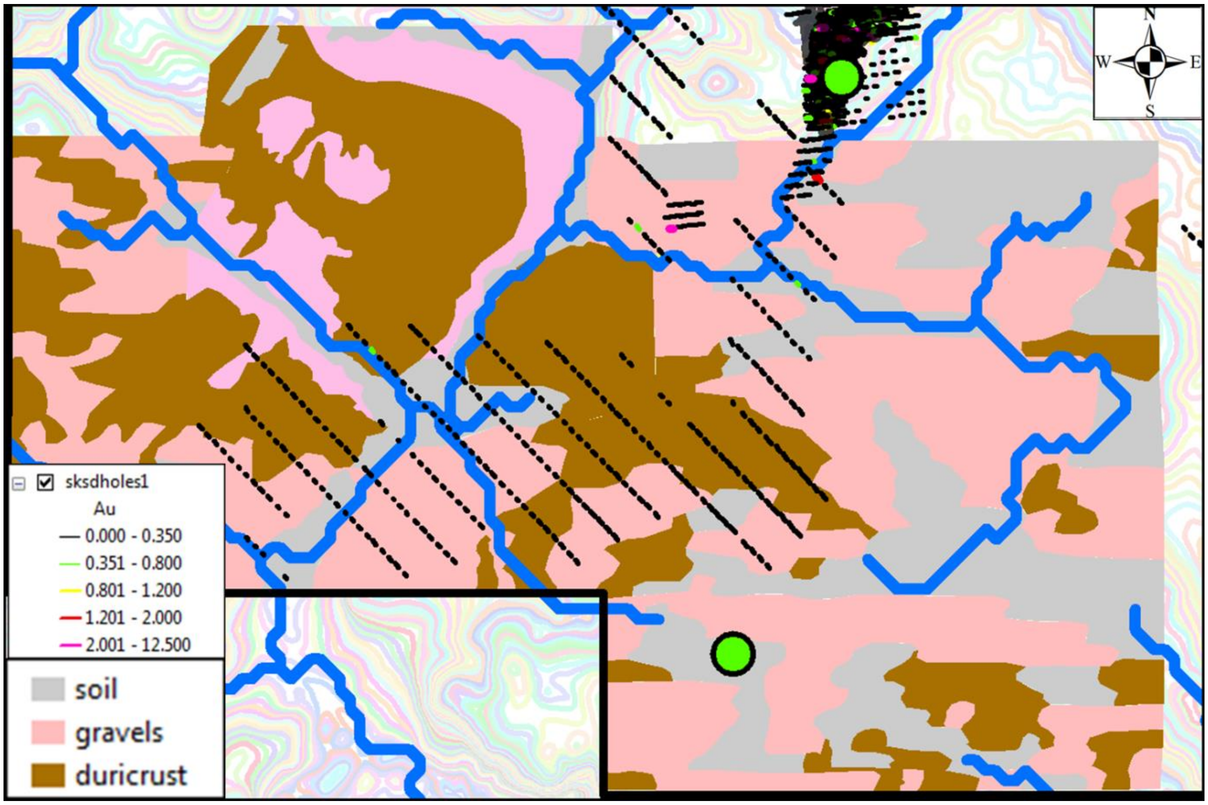

Figure 45: Kourouda south west regolith map with the drill holes in black dot.

8.5.3.4 Drilling

The area has been test through the air core drilling and is showing a positive result with low grade. The air core drilled holes on a north-west oriented grid at a 400 x 100m spacing. Several grade intersections were reported of more than 3 m. Of particular interest is the mineralised intercepts in the northern part, which are near an interpreted north-east structure and may have some potential for expansion.

8.5.4 Niono Target

8.5.4.1 Background

The Niono target is defined base on a soil geochemical Au-anomaly covering an area of 3.94km2 and the lithological contact with the north-south structure.

8.5.4.2 Surface Soil

A total of 1,325 soil samples were collected and assayed for gold and arsenic. Based on the assay results after data validation, a descriptive statistics study (**Table 11**) is done in the area. A histogram plot showing the different populations and a log probability plot showing the variation of the trend line are presented in the graphs below.

Table 11: Summary of the descriptive statistics of Niono Target

	Au (ppb)	As (ppm)
Mean	18.84	20.80
Standard Error	2.71	0.70
Median	7.00	10.00
Mode	1.00	10.00
Standard Deviation	93.02	23.33
Sample Variance	8651.89	544.45
Kurtosis	333.56	12.53
Skewness	17.45	3.00
Range	2065.00	231.00
Minimum	1.00	10.00
Maximum	2066.00	241.00
Sum	22153.00	23315.00
Count	1176.00	1121.00
Largest(1)	2066.00	241.00
Smallest(1)	1.00	10.00
Confidence Level(95.0%)	5.32	1.37

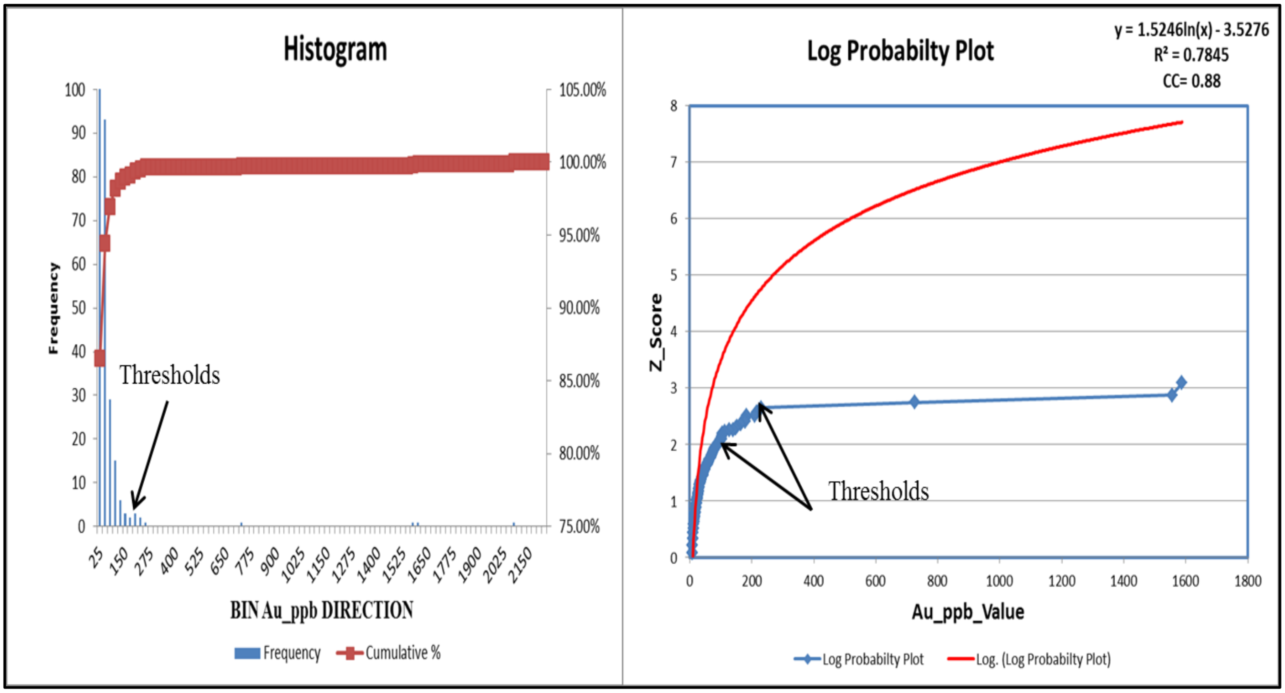

Figure 46: Graph showing the histogram and log probability plot (Z_Score) of Au_ppb highlighted the anomalous threshold value of Niono target.

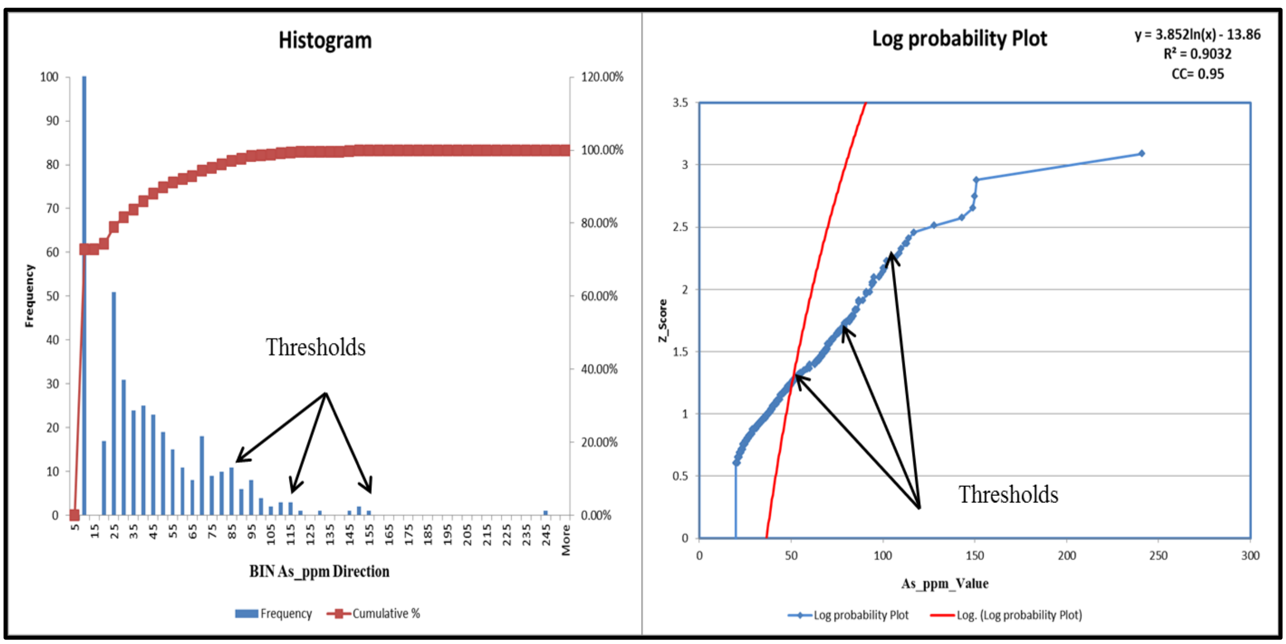

Figure 47: Graph showing the histogram and log probability plot (Z_Score) of As_ppb highlighted the anomalous threshold value of Niono target.

8.5.4.3 Regoliths

The Niono target is bounded by a (primary) duricrust bench topping a hill in the north east. Duricrust gravels are developed on the slopes as the topography gives way to form a valley in the central to south western parts. The valley cover consists of saprolitic clays, gravels (with angular bedrock clasts) and soils surrounding secondary/later developed duricrust islands and associated gravels, (**Figure 48**).

The Niono targets are interpreted to have a shallow weathering profile due to the angular bedrock clasts found in saprolite and as scree, along with bedrock outcrops with a thin, mainly residual regolith cover. The area host in-situ outcrops of meta-sediments, saprolite and mottled saprolite with quartz veining broadly developed. Bedding trends roughly north-west/south-east but folding is suggested to have occurred in the area. Structural quartz vein measurements and Au assays haven't aided the identification of a high potential vein set. The area is mainly considered to have fresh rock potential.

Active mining takes place across large areas within the target. In the south east activities focus on shallow pits exploiting near surface saprolitic material, quartz vein scree was also observed here.

Of greater interest are the north-eastern and south-western areas where miners are actively targeting quartz veins developed within in-situ saprolite as they burrow thru duricrust and gravel.

The area to the north-west of the target has seen little activity as rough terrain obstructs ease of access.

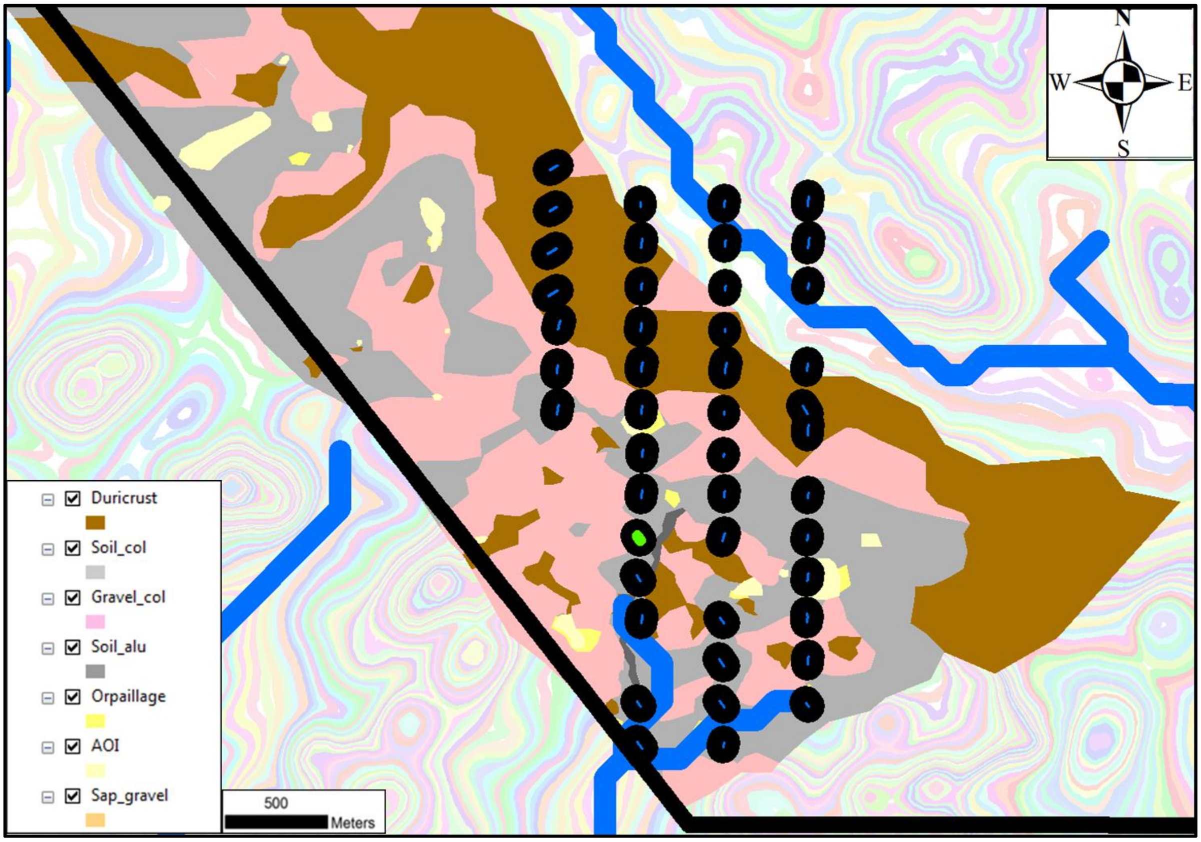

Figure 48: A topographic high gives way to a valley developing towards the south west, as shown by the Niono regolith map. Mining activities in the south western and north eastern parts are exploiting quartz veins developed within saprolite material.

8.5.4.4 Drilling

The area has been tested by a number of air core holes.

Figure 49: (A) & (E) Folded veins, varying from tight to open, from ar. (B) Highly ferruginised greywacke with quartz veining. (C) Ferruginised greywacke and siltstone units play host to a 10cm thick quartz vein. (D) Quartz vein scree material at area 1, similar sized scree boulders were observed across the target. (F) An interpreted calcareous chert or a calc-silicate unit outcrops at area 4. (G) 15cm thick quartz vein scree found. (H) Quartz vein in saprolite mined. (I) interpreted normal fault highlighted by the orange line as it displaces a quartz vein (red).

8.5.5 Seguelen Komatiguia Target

8.5.5.1 Background

The Seguelen-Komatiguia target is best defined in the regional gold in soil geochemical survey which occurs north of the Seguelen pit (Kintinian). The target is also in a north-west structural corridor which encompasses Kintinian and Eureka North. The target was given a top high priority due to its strong, consistent and broad geochemical signature.

The EM SPECTREEM (Siguiri_Tauz) and the total magnetic field images define a north-west/south-east striking thrust or fault along the Kintinian (Seguelen) mineralized zone. Recent mining activities have exposed the lithological contact between the Kintinian and Fatoya Formations.

8.5.5.2 Surface Soil

A total of 6,610 soil samples were collected and assays for gold and arsenic. Based on the assays results after data validation, a descriptive statistics study (**Table 12**) was completed for this target. A histogram plot showing the different populations and a log probability plot showing the variation of the trend line are presented in the graphs below.

Table 12: Summary of the descriptive statistics of Seguelen Komatiguia target

	Au (ppb)	**As (ppm)**
Mean	86.26	99.66
Standard Error	6.08	7.97
Median	10.00	55.00
Mode	1.00	10.00
Standard Deviation	493.93	346.16
Sample Variance	243967.81	119823.46
Kurtosis	342.96	1440.47
Skewness	16.45	35.65
Range	13399.00	14140.00
Minimum	1.00	10.00
Maximum	13400.00	14150.00
Sum	570194.00	188152.00
Count	6610.00	1888.00
Largest(1)	13400.00	14150.00
Smallest(1)	1.00	10.00
Confidence Level(95.0%)	11.91	15.62

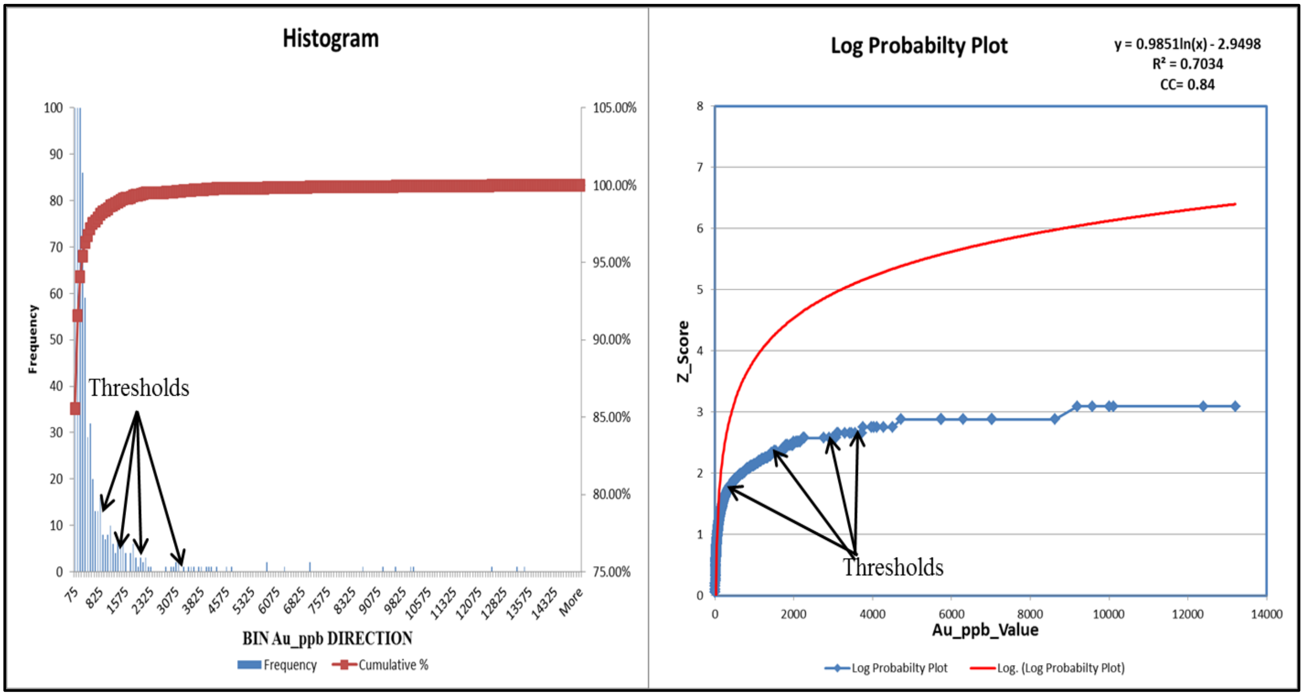

Figure 50: Graph showing the histogram and log probability plot (Z_Score) of Au_ppb highlighted the anomaly threshold value of Seguelen Komatiguia Target.

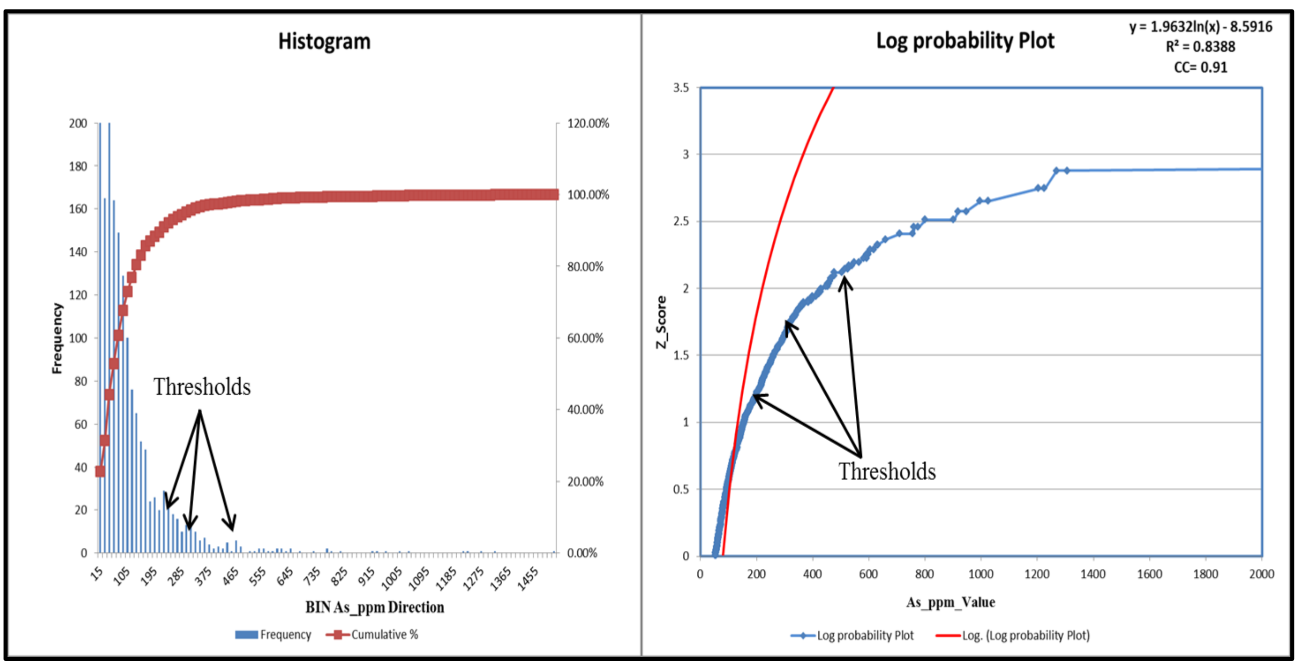

Figure 51: Graph showing the histogram and log probability plot (Z_Score) of As_ppb highlighted the anomaly threshold value of Seguelen Komatiguia Target.

8.5.5.3 Regoliths

The Seguelen Komatiguia target is situated on the edge of an escarpment. Lateritic duricrust is developed to the south of the escarpment on the higher elevations. The lower elevated ground to the north of the escarpment has less laterite capping and consists predominantly of gravels and soils made up of laterite- and saprolite colluvium.

The predominant lithological units at Seguelen are meta-sediments and to a lesser degree meta-volcaniclastic and meta-tuffs. The meta-sediments dip at moderate angles to the greywackes and are made up of sandstones, siltstones and minor conglomerates and/or breccia.

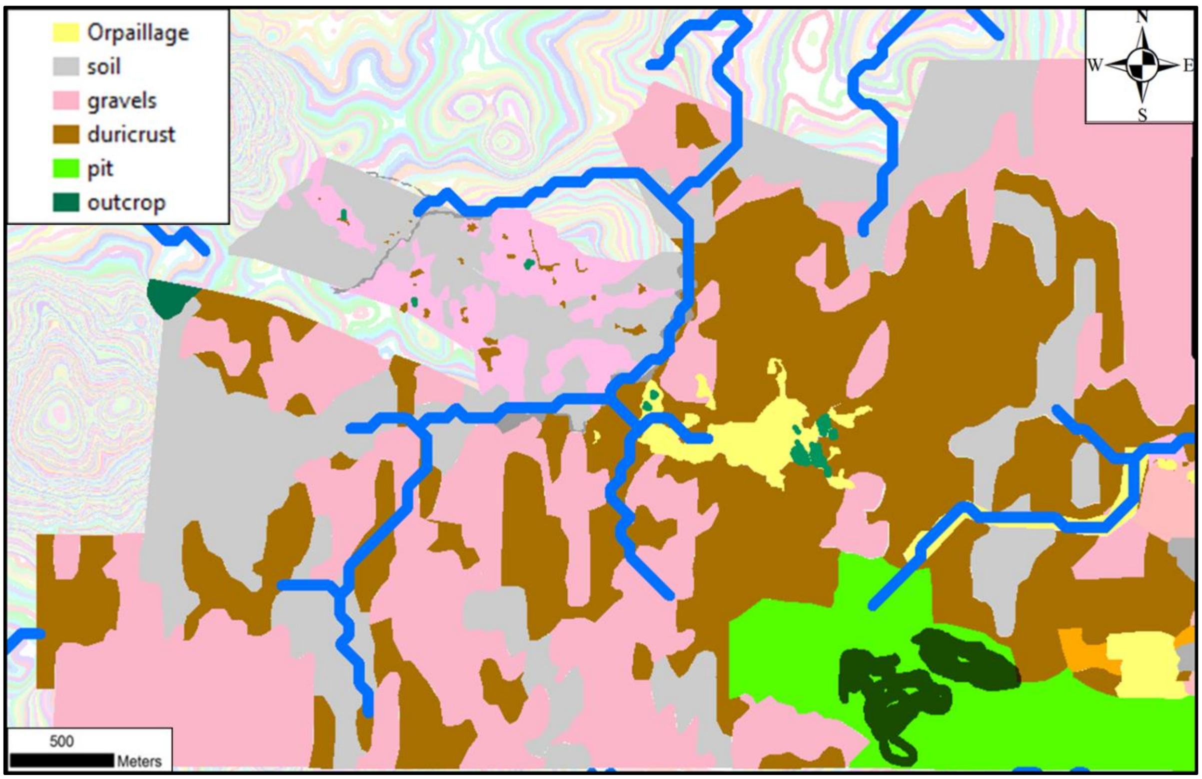

Figure 52: Seguelen-Komatiguia regolith map where intense orpaillage activities are ongoing.

8.5.5.4 Drilling

The target was tested through Air core drilling and no economic mineralisation was intersected. The air core drilled holes on a north-south oriented grid at a 400 x 100m spacing aim to test the high geochemical anomaly. In addition two diamond drill holes were also drilled to support the geological interpretation and structure orientation within the area.

The thickness of the laterite cover varies from 2 to 12m and the regolith itself extends at depth between 30 and 150m. On average the transitional zone is approximately 65m below surface.

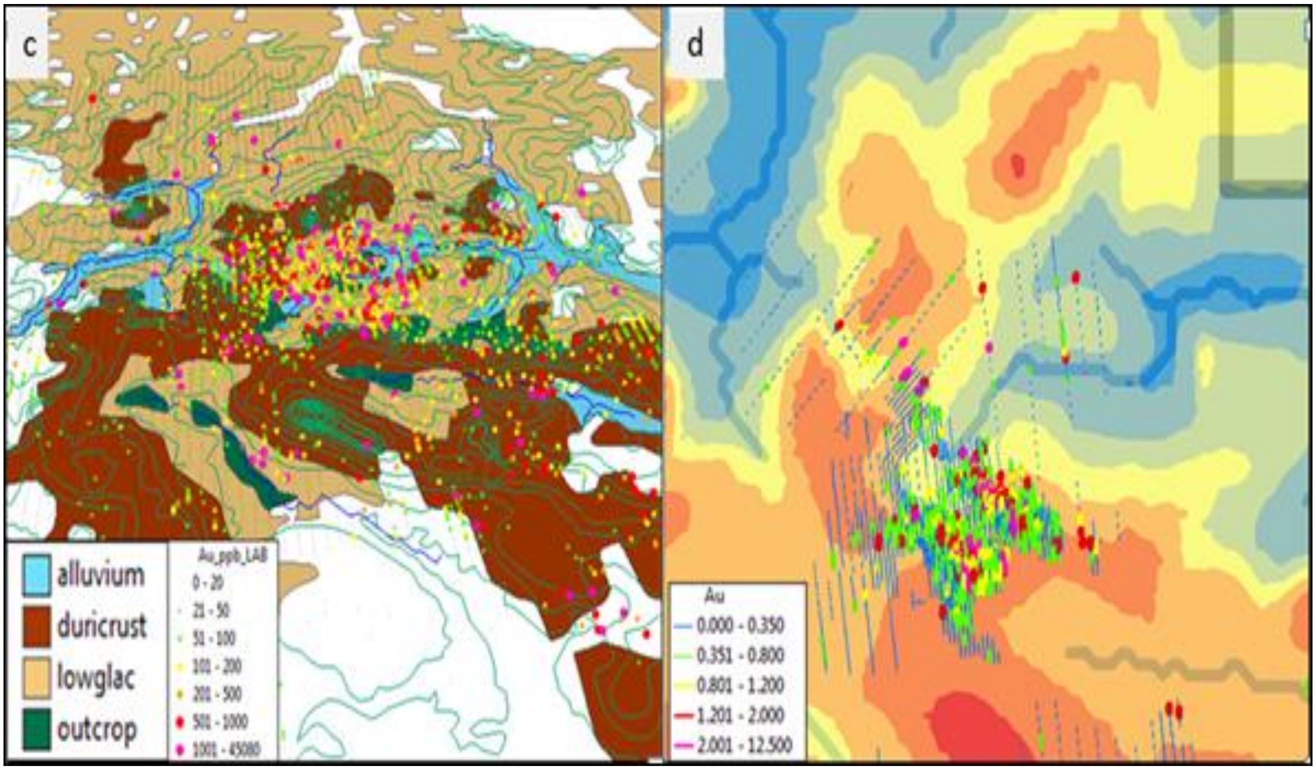

Figure 53: Left: Gold dispersion in soil over the regolith map showing approximately which types of sample were collected. Right: drill hole with Au intercepts over the digital terrain model (dtm) map showing the direction of the drainage (d)

8.5.6 Silakoro Target

8.5.6.1 Background

The Silakoro target was generated based on the north-south-trending zone associated with low grade geochemical gold anomalies, presence of artisanal mining activities and the contact between the **K**intinian and **F**atoya **F**ormations. A soil geochemical anomaly trend is well correlated to the geophysical response.

8.5.6.2 Surface Soil

A total of 1,401 soil samples were collected and assayed for gold and arsenic. Based on the assay results after data validation, a descriptive statistic study (**Table 13**) undertaken for area. A histogram plot showing the different populations and a log probability plot showing the variation of the trend line are presented in the graphs below.

Table 13: Summary of the descriptive statistics of Silakoro target

	Au (ppb)	**As (ppm)**
Mean	25.70	26.07
Standard Error	4.55	0.81
Median	5.00	10.00
Mode	1.00	10.00
Standard Deviation	166.56	28.94
Sample Variance	27742.71	837.26
Kurtosis	292.95	31.23
Skewness	16.22	3.93
Range	3499.00	401.00
Minimum	1.00	10.00
Maximum	3500.00	411.00
Sum	34470.00	32984.00
Count	1341.00	1265.00
Largest(1)	3500.00	411.00
Smallest(1)	1.00	10.00
Confidence Level(95.0%)	8.92	1.60

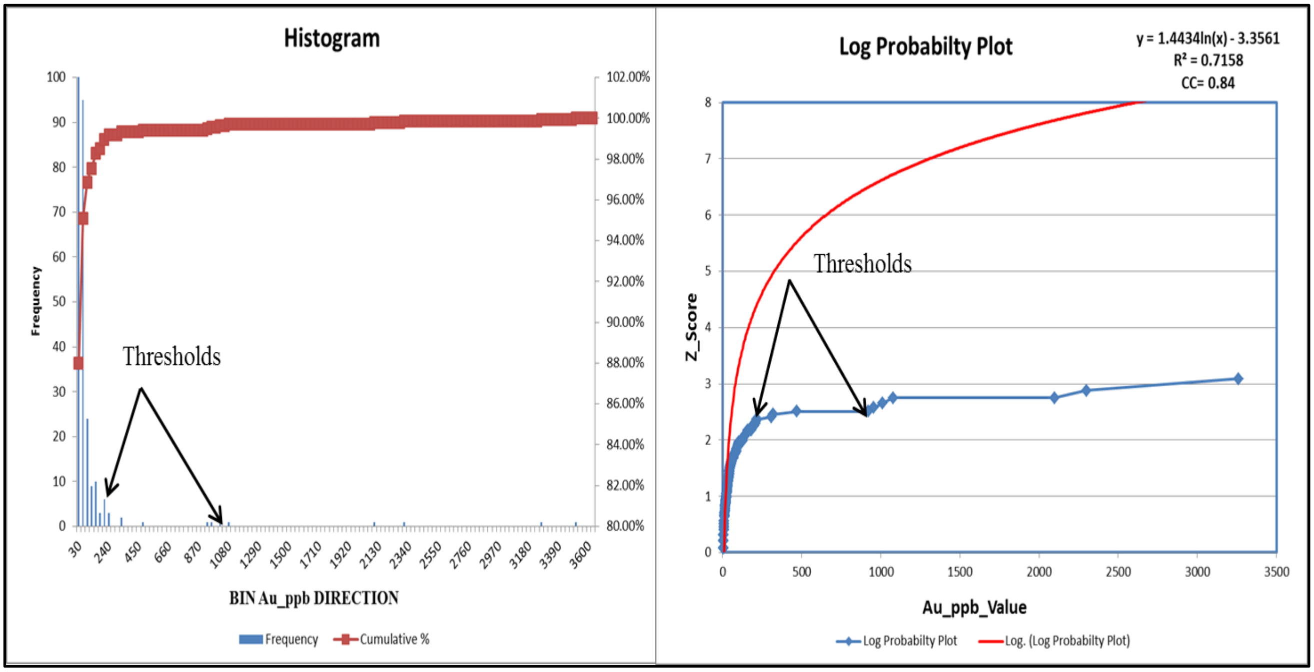

Figure 54: Graph showing the histogram and log probability plot (Z_Score) of Au_ppb highlighted the anomalous threshold value of Silakoro Target.

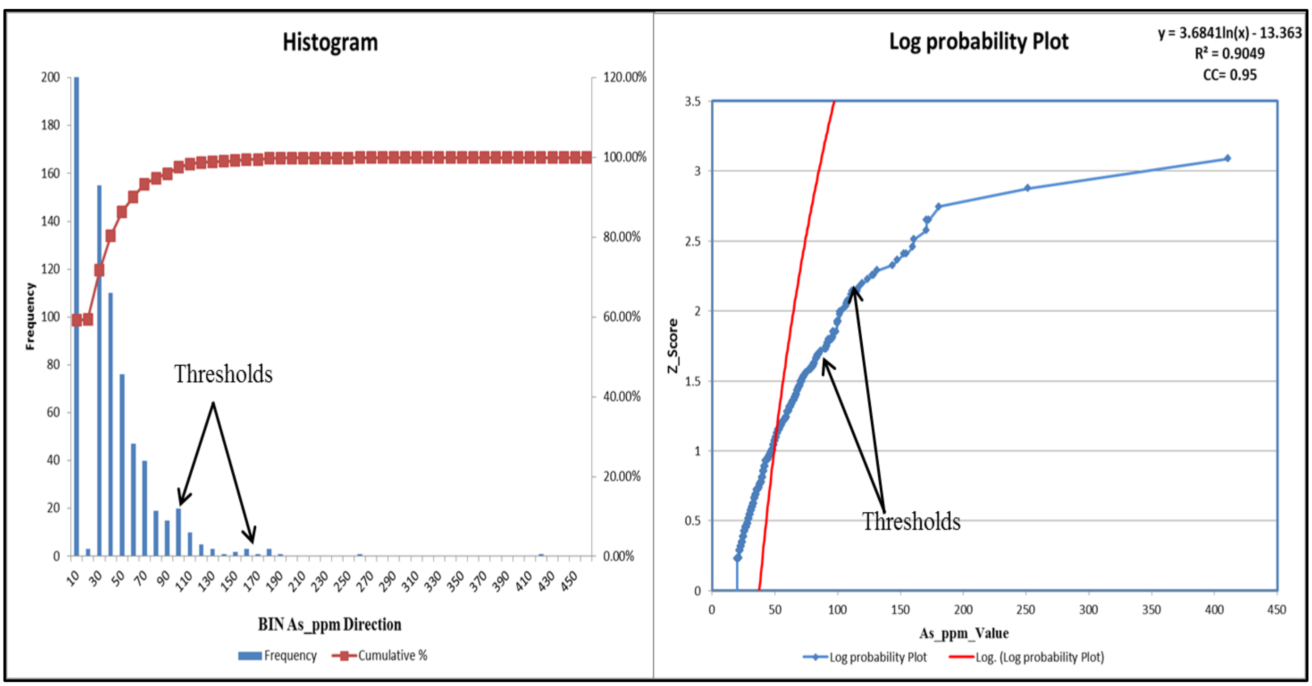

Figure 55: Graph showing the histogram and log probability plot (Z_Score) of As_ppb highlighted the anomalous threshold value of Silakoro Target.

8.5.6.3 *Regoliths*

Hills developed to the west of the target are covered by duricrust and associated gravels. Lower lying areas consist of aeolian and or alluvial soil with gravel patches and duricrust islands, (**Figure 56**). These islands suggest duricrust isn't far from surface elsewhere and underlies most of the target.

The Silakoro North and Main targets are covered by thick transported duricrust, gravels and soils, with almost no residual cover (possible saprolite exposure around river banks) or outcrop. The Silakoro Main target is/was subject to massive artisanal mining activity targeting mottled saprolite beneath duricrust. Within the targets mapped, the Silakoro Main target has the highest oxide potential and could host small, oxide deposit.

Artisanal mining activity to the north east is actively busy washing/concentrating material brought from elsewhere in block 1 (Seguelen pits). To the south of this wash area historic activities exploited quartz veins beneath cover. Holes are burrowed thru alluvial soils into, presumably, saprolite where quartz veins are in-situ. The target have the one deepest artisanal mining pit in the area where miners are actively quarrying thru some 3m thick duricrust to reach the mottled saprolite zone beneath (**Figure 56**). There is no bedrock or quartz vein clasts were observed in the area.

Metal detectors are used to extract gold from transported gravel on the hill slopes in the west.

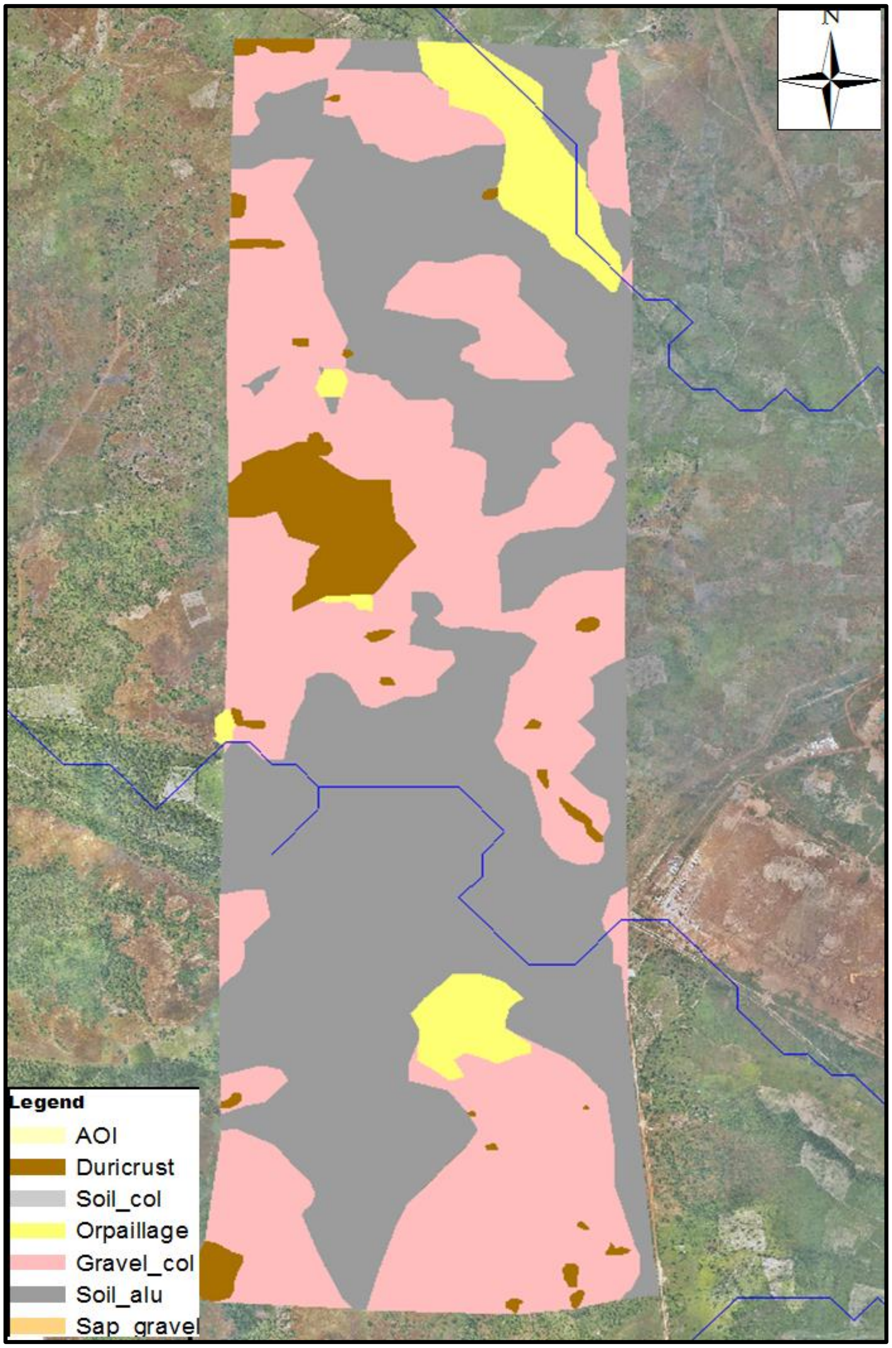

Figure 56: Regolith map of the Silakoro target, note the extensive mining activities in the central and northern-east parts.

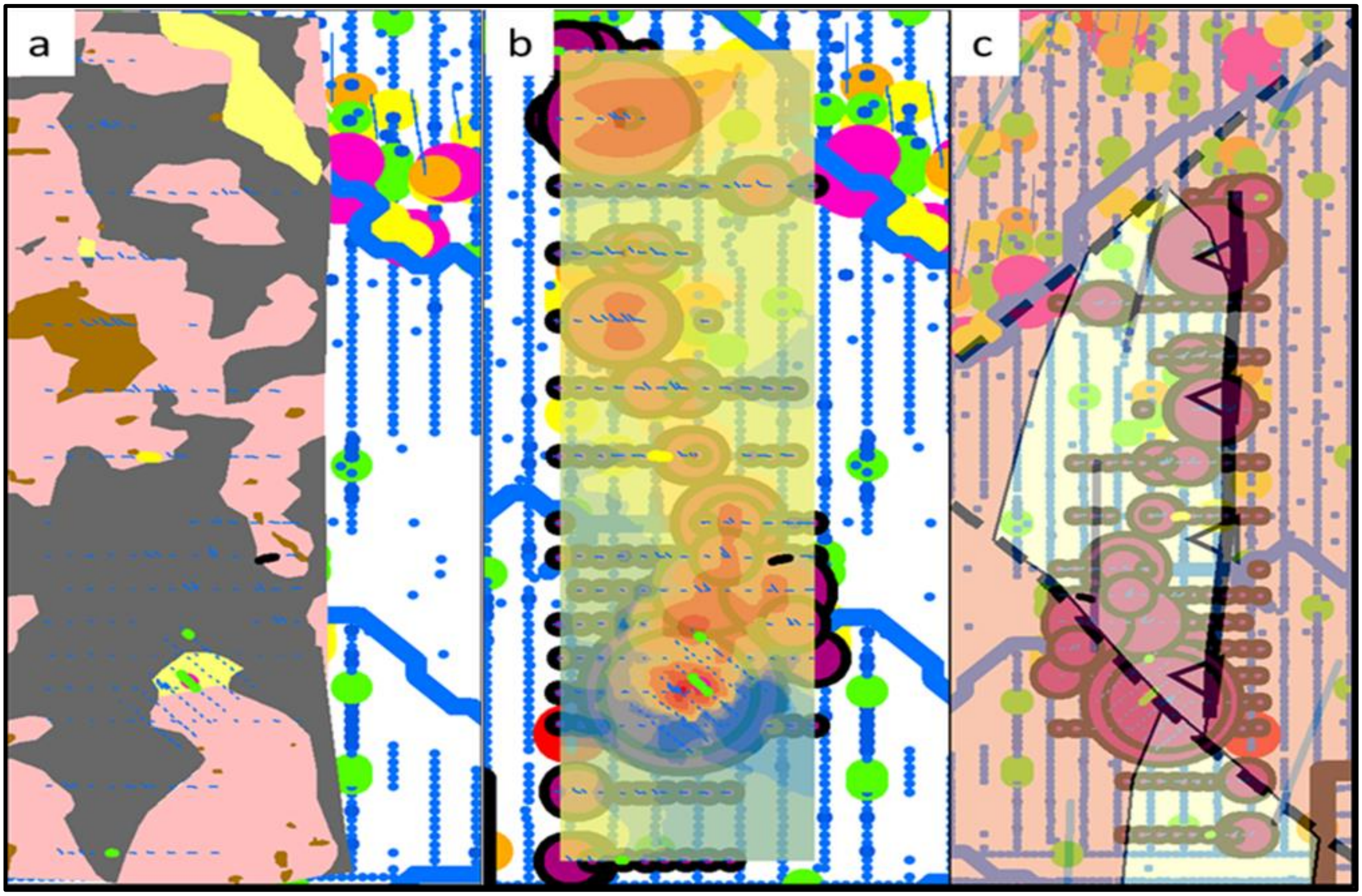

Figure 57: Regolith map over soil geochemistry (a); interpreted Inverse Distance Weighting (IDW) (b); geological map showing the high grade sitting on the lithological contact and geophysical trend (c) (this study 2014).

8.5.6.4 Geophysics

A part of AEMs, the entire Silakoro area was covered by ground Induced Polarization (IP) survey. Most of the area is covered by a laterite capping and this causes high ground resistance and increased difficulty of obtaining reliable readings. This also slows the production rate. To counter this, the line spacing has been reduced from 200m to 150m. This has in turn resulted in higher data resolution.

8.5.6.5 Drilling

The reconnaissance Air core drilling programme at a 400m line by 100m holes spacing was drilled over the prospect. Gold mineralisation was intersected along a thin N-S-trending structure that widened up to the south. A few Reverse Circulation (RC) holes were drilled for further follow up of the mineralized zone and obtain more information on the nature of the Au-mineralisation (rock types and continuation of the mineralisation into the fresh rock). Two diamond holes were drilled to support the geological and structural information within the area.

The observation indicated that the gold mineralisation at Silakoro occurs in different styles that primarily vary with the host rock type. The most common style of mineralisation is associated with quartz sulphide veins. The veins occur especially in the fine- to medium-grained clastic rock types such as the green Kintinian shales and siltstones as well as in the quartzites and greywackes.

The second style is associated with breccias/conglomerates and generally occurs in the form of finely disseminated sulphides (pyrite, chalcopyrite, and sphalerite). Au-mineralisation in fine-grained, disseminated sulphides was also observed in the cherty-quartzites. Disseminated sulphides without any positive gold values were encountered in the grey calcite limestone and in the coarse-grained black quartzite.

Both the vein style mineralisation and breccias with disseminated sulphides yielded high grade gold intersections between 5- 47g/t per meter interval over several meters. Medium-grade intercepts ranging between 1- 5g/t per meter interval are also hosted by veins as well as by disseminated mineralisation in breccias, quartzites and limestones.

Chapter 9 : Discussion

The discussion attempts to understand the distribution and correlation between gold and arsenic in the laterite-gravel-soil and their relationship with the regolith landforms.
Also the proposed solution of the targeting approaches is used for exploring in the deep weathering and lateritic covers where outcrop is rare or absent.

9.1 Gold mobility during lateritic deep weathering

The formation and evolution of deeply weathered, lateritic regolith may result in the mobilization and redistribution of Au and have considerable significance to the surface expression of mineralization (Butt, 1988; Gray et al., 1992). During lateralization in seasonally humid, warm to tropical climates, oxidation at the weathering front deep below the water-Table produces neutral to acid conditions, with lower pH values favored by felsic rocks and high sulphide contents. Gold associated with tellurides or held in the lattice of the sulphides and other minerals may be released, but the free metal remains largely immobile due to the absence of suitable complex ligands. Thiosulphate ions, which can complex Au, are formed only by sulphide oxidation in neutral to alkaline conditions, and concentrations of chloride ions and organic matter are very low. Accordingly, although some corrosion and reduction of size occurs, primary Ag-rich grains persist through the saprolite and into the ferruginous zone, and lateral dispersion into saprolitic wall rocks is minimal. Gold and silver may be mobilized; however, if high concentrations of carbonate are present in the primary mineralization, the oxidation of pyrite in such an alkaline environment produces thiosulphate. Lateral dispersion of Au is evident towards the top of the profile, particularly in the lateritic residuum and mottled horizons.
This is due to (i) residual concentration, colluvial transport and surface wash of Au grains during land surface reduction and (ii) to mobility, either in solution or as particulates (*e.g.*, colloids or very fine grains of free metal). Some Au may also be contributed directly to the soil after uptake by plants. Reduction of the complexes results in incorporation of fine-grained Au with low Ag contents in Fe oxides, particularly in the lower part of the lateritic residuum and in the mottled zone. The resultant Au distribution in the residual regolith is typical of deposits in the humid

tropics (Mborguéné, Cameroun, and Banankoro, Mali: Freyssinet *et al.*, 1989 a, b; Freyssinet *et al*., 2005).

9.2 Gold and Arsenic distribution in the Laterite-Gravel-Soil and their correlation

The present discussion is based on three interesting aspects: (1) the distribution of Au and As in the residual and or transported duricrust, associated with similar pebbles and clasts as those that are found in the ferruginous lateralized gravel bed; (2) the presence of felsic meta volcanogenic suite in other parts of the area, without expressive lateritic capping (north, northwest of the Block1); and (3) orpaillage workings of primary Au (e.g. Silakoro) and secondary Au in most parts of Block1. The study of the drainage further indicates the lateralized gravel bed as the possible source for Au in the lower level and its proximity.

The gold anomaly in this area is considered to be transported as it follows the gravels on the low glacis and alluvium along the rivers adjacent to incised and highly elevated duricrust ridges. The Seguelen deposit occurs on the contact between the **F**atoya and **K**intinian **F**ormations.

Lateritic crusts are indurated and compact providing cover any bed rock type. The presence of a deep-brown coloration is indicative of goethite alteration, which may occur either as an intergranular material between rocks fragments or as a total cover.

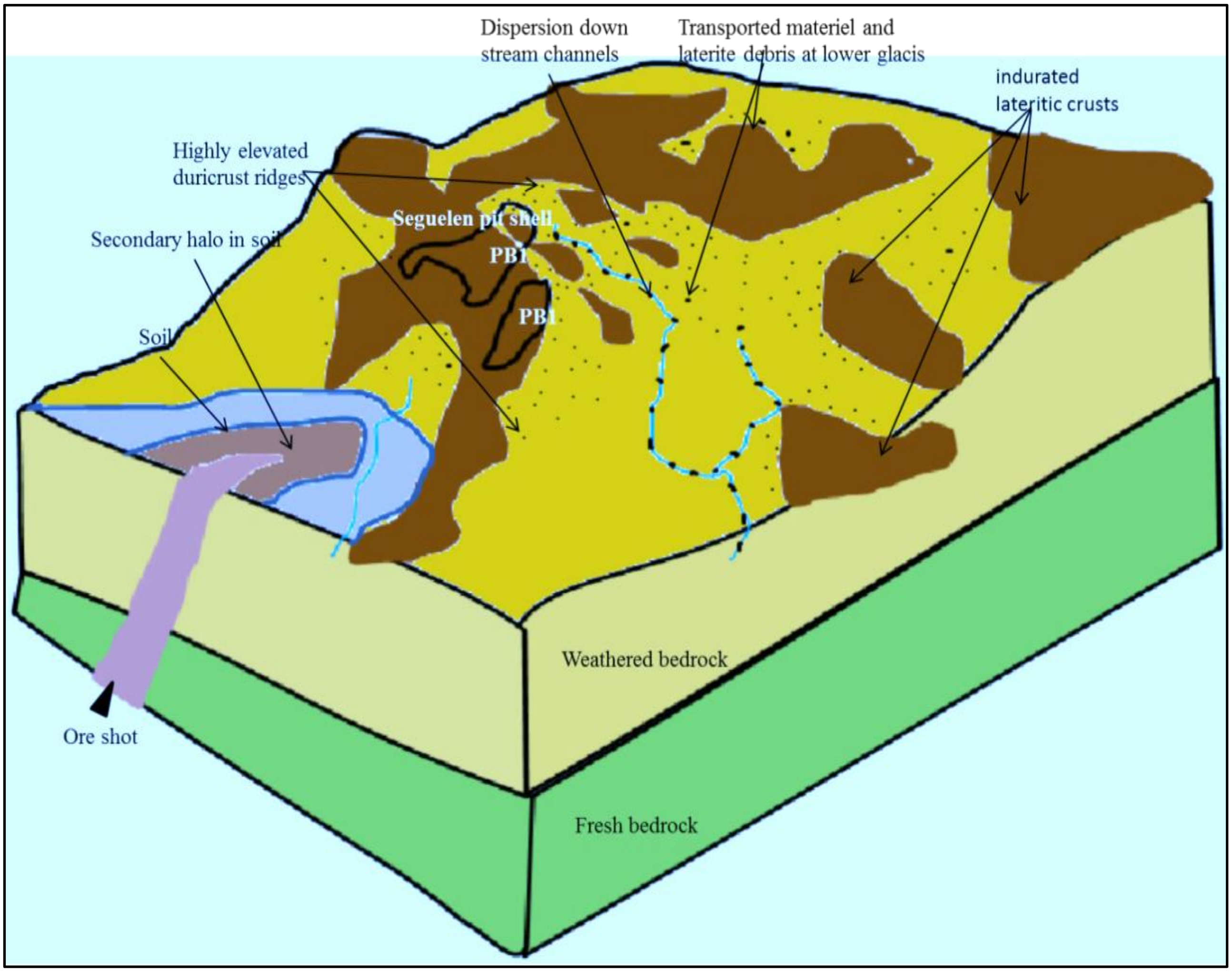

Figure 58: A conceptual regolith-landform model (from Butt and Smith, 1980) used for understanding geochemical dispersion from deeply weathered ore deposits. Superimposed on their model are the Seguelen pits, Push back 1 and 2 are shown.

9.3 Multi-element occurrence in the regolith and the predicted correlation with gold mineralisation.

Three section lines with a total of 1095 samples from the RC chips were selected from the Sokunu deposit to conduct a multi-element analysis of the samples.

The XRF analytical method is used to test 32 elements and these results are compared with the analysis for gold using the Leachwell and Fire assay methods.

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The correlation of all 32 elements with gold is calculated. A value of 1 indicates a perfect correlation whereas a -1 value represents a negative correlation. Elements with a correlation of ≥ 0.3 are highlighted in pink in the Table below.

Table 14: Table of correlated elements highlighted with Au and As

	Au	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Rb	Sr	Zr	Mo	Ag	Cd	Sb	W	Hg	Pb	Th	Ba
Au	1.00																									
K	-0.12	1.00																								
Ca	-0.02	0.01	1.00																							
Ti	0.08	0.43	0.01	1.00																						
V	0.08	0.53	0.01	0.76	1.00																					
Cr	0.15	0.16	0.00	0.71	0.80	1.00																				
Mn	-0.09	-0.11	0.04	0.03	0.02	-0.01	1.00																			
Fe	0.07	-0.46	-0.01	-0.01	0.00	0.14	0.18	1.00																		
Co	0.06	-0.44	-0.01	0.01	0.01	0.13	0.21	0.98	1.00																	
Ni	-0.05	0.03	0.00	-0.04	0.01	0.00	0.10	-0.02	-0.01	1.00																
Cu	0.06	0.09	0.07	0.11	0.13	0.08	-0.01	0.26	0.28	-0.02	1.00															
Zn	-0.11	-0.04	0.05	-0.18	-0.15	-0.20	0.38	0.27	0.28	0.49	0.17	1.00														
As	0.38	-0.33	-0.04	0.03	0.11	0.24	-0.10	0.54	0.53	-0.10	0.23	-0.03	1.00													
Se	0.04	-0.13	0.00	0.04	0.08	0.14	0.01	0.18	0.21	-0.01	0.05	-0.02	0.12	1.00												
Rb	-0.12	0.82	0.00	0.14	0.25	-0.15	-0.15	-0.45	-0.44	0.03	0.03	-0.06	-0.39	-0.12	1.00											
Sr	0.04	0.36	0.03	-0.10	0.06	-0.13	-0.16	-0.34	-0.35	0.05	-0.04	-0.09	-0.10	-0.06	0.55	1.00										
Zr	0.19	-0.25	-0.05	0.34	0.13	0.28	-0.10	0.05	0.04	-0.14	-0.12	-0.35	0.21	0.05	-0.19	0.06	1.00									
Mo	-0.03	0.05	-0.01	0.05	0.14	0.08	0.00	0.07	0.07	-0.02	-0.05	-0.04	-0.03	0.10	0.04	-0.05	0.03	1.00								
Ag	-0.01	0.01	0.00	-0.02	-0.03	-0.03	-0.01	0.01	0.01	0.00	0.01	0.03	-0.02	0.00	0.03	-0.03	-0.03	0.00	1.00							
Cd	-0.02	-0.01	0.00	0.00	-0.02	0.00	0.07	-0.01	-0.02	-0.01	-0.02	0.02	-0.03	0.00	-0.03	-0.03	-0.02	-0.01	0.00	1.00						
Sb	0.01	-0.10	0.00	0.02	0.04	0.07	0.01	0.15	0.15	-0.01	-0.01	-0.02	0.07	0.25	-0.08	-0.06	0.00	0.08	0.00	0.00	1.00					
W	0.35	-0.13	-0.01	0.09	0.08	0.21	-0.08	-0.06	-0.07	-0.03	0.01	-0.08	0.27	0.05	-0.17	-0.04	0.20	0.00	-0.01	-0.01	-0.01	1.00				
Hg	-0.04	0.30	-0.03	0.18	0.16	0.01	-0.12	-0.13	-0.13	-0.05	0.02	-0.13	-0.16	-0.03	0.41	0.23	0.08	-0.02	0.05	-0.03	-0.04	-0.09	1.00			
Pb	0.11	-0.34	-0.01	-0.06	0.10	0.26	0.04	0.76	0.70	-0.03	0.11	0.01	0.53	0.16	-0.32	-0.19	0.05	0.07	-0.01	-0.01	0.13	-0.04	-0.09	1.00		
Th	0.02	0.01	-0.01	0.12	0.11	0.05	-0.04	0.06	0.07	-0.05	-0.04	-0.09	-0.02	0.06	0.10	0.12	0.20	0.13	-0.02	-0.02	0.04	-0.02	0.13	0.03	1.00	
Ba	-0.12	0.73	0.01	0.08	0.20	-0.22	-0.08	-0.45	-0.44	0.01	0.02	-0.02	-0.38	-0.12	0.92	0.53	-0.19	0.02	0.01	-0.02	-0.10	-0.18	0.35	-0.33	0.11	1.00

Down hole plots were made to show and explain the distribution or behaviour of certain element's compared to gold concentrations and also to establish the suit of the element associated with gold mineralisation, from which a pathfinder suite can be recognised.

The study identified only arsenic (As) and tungsten (W) as the gold-associate suite having a correlation of > 0.3. But in gold exploration the best pathfinder element is arsenic with a correlation of 0.379.

There is no gold associated with Ag, Bi, Sn, Sb, Se, S and Hg. Arsenic is correlated with Fe, Co and W.

The plot on figures below shows the occurrence of high arsenic and iron content and is well distributed near the surface.

The identified elements As & Fe and W may be used as pathfinders in future exploration programmes and geological modelling.

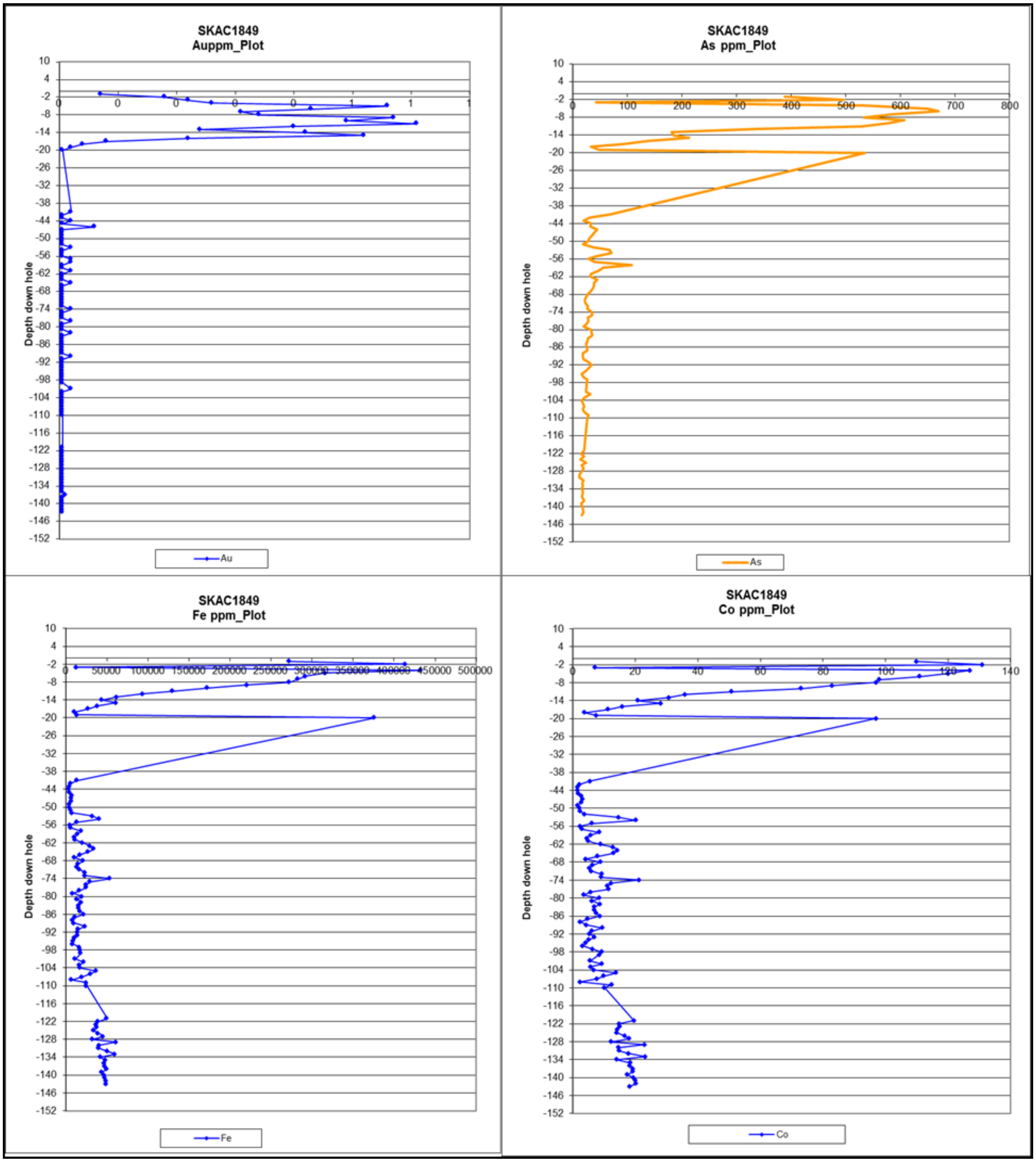

Figure 59: Down-hole plot of the elements As, Fe, Co showing a strong correlating with gold mineralisation and concentrated in the near surface environment.

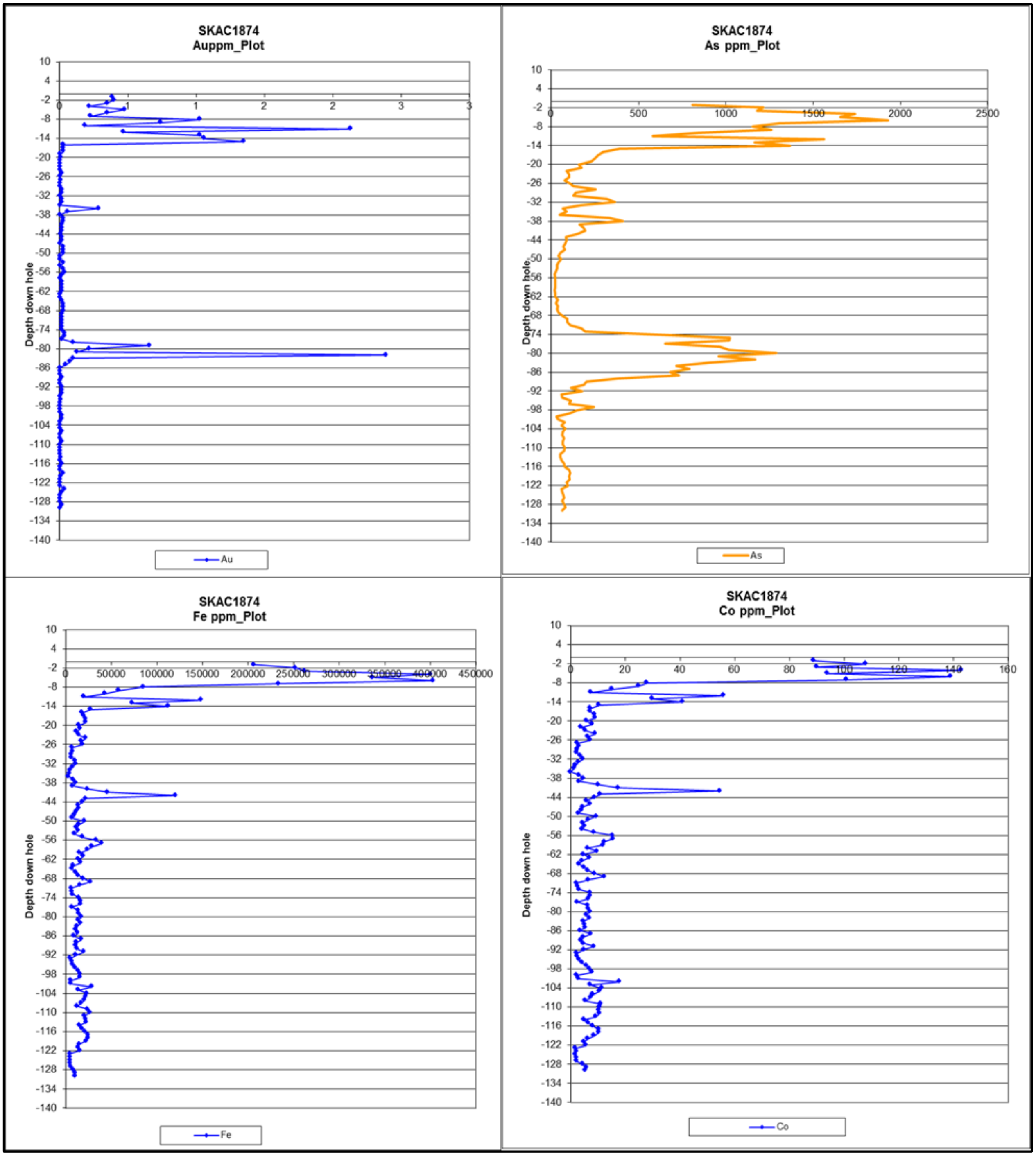

Figure 60: Down-hole plot showing elements correlating well with arsenic mineralisation and showing high As, Fe, Co values near surface.

Table 15: Highlighted elements correlated to gold and arsenic (pink) and additional elements associated with the Siguiri style mineralisation. Anomalous values were also calculated as reference.

					Anomalous Values			
Elements	Correlation with Au	Mean	Median	Standard Deviation	Crustal levels (Levinson, 1974)	Histogram (20 bins)	Anomalies (2xSTD+Mean)	Ave (STD+Hist)
Au	1.000	0.242	0.050	0.513	0.005	0.700	1.267	1.213
K	-0.117	15970.008	15709.000	4928.043	2.900		25826.094	4928.043
Ca	-0.020	1.614	0.000	25.883	4.150		53.380	25.883
Ti	0.079	2629.500	2512.000	609.264	0.450		3848.027	609.264
V	0.080	62.669	60.000	15.222	135.000		93.113	15.222
Cr	0.152	91.318	86.000	25.949	100.000		143.215	25.949
Mn	-0.090	91.230	38.000	170.804	950.000		432.838	170.804
Fe	0.068	43391.780	21276.000	71744.435	5.630	180000.000	186880.651	251744.435
Co	0.058	16.564	8.900	23.204	25.000	59.500	62.971	82.704
Ni	-0.054	2.450	0.000	16.027	75.000		34.505	16.027
Cu	0.060	40.990	36.000	30.977	55.000	150.000	102.944	180.977
Zn	-0.107	18.417	7.600	34.309	70.000		87.034	34.309
As	0.379	322.992	194.000	393.429	15.000	1800.000	1109.851	2193.429
Se	0.037	0.014	0.000	0.239	0.050		0.491	0.239
Rb	-0.122	110.936	112.900	35.328	90.000		181.593	35.328
Sr	0.044	35.234	31.000	20.639	375.000		76.512	20.639
Zr	0.188	179.537	166.000	58.146	165.000		295.829	58.146
Mo	-0.030	0.799	0.000	5.049	1.500		10.898	5.049
Ag	-0.014	0.005	0.000	0.175	0.070		0.356	0.175
Cd	-0.018	0.011	0.000	0.267	0.200		0.544	0.267
Sn	#DIV/0!	0.000	0.000	0.000	2.000		0.000	0.000
Sb	0.006	0.067	0.000	1.110	0.200		2.287	1.110
W	0.353	1.026	0.000	4.690	2.000	18.000	10.405	22.690
Hg	-0.038	1.809	0.000	2.997	0.080		7.804	2.997
Pb	0.109	1.967	0.000	10.065	12.500		22.098	10.065
Bi	#DIV/0!	0.000	0.000	0.000	0.170		0.000	0.000
Th	0.023	35.150	0.000	59.839	10.000		154.827	59.839
U	#DIV/0!	0.000	0.000	0.000	2.700		0.000	0.000

9.4 Regolith mapping

The regolith mapping results demonstrated many of the surficial regolith materials in the area comprise transported sandy-clays and ferruginous cuirasse developed in colluvium. Surface gold and arsenopyrite (Au-As) anomalies generally reflect secondary/tertiary dispersions producing broad and patchy surficial re-distribution of Au-As in a variety of regolith material through alluvial-colluvial processes.

An alluvial and elluvial artisanal mining operation (such as dredging along drainages and digging into the duricrust using metal detector) has also affected the patterns of surficial geochemical dispersion through contamination.

9.5 Soil geochemistry

Soil geochemistry result demonstrated that most the anomalies are transported. The surficial Au-As anomalies may not reflect underlying geology and genuine evidence of underlying Au mineralisation, except where surficial regolith is residual. Lateral geochemical dispersion in regolith over mineralized primary structures appears to be limited and thus geochemical haloes in regolith will be relatively narrow. The lithological contact between the different formations remained the best anomalies to follow for further targeting.

Planning the soil sampling together with the regolith mapping at the first exploration stage within the assay result interpretation can predict if the anomalies are in situ or transported.
The geochemical analyses, such as Aqua Regia together with XRF methods can measure the concentrations of gold and associate elements. The assay results are easily interpreted and the correlation or relationships of elements are outlined. The concentration of the pathfinder elements can be also determined.

9.6 Targeting

In June 2014 the Centre for Exploration Targeting (CET) from the University of Western Australia represented by ***Professors Nicolas Thébaud*** and ***John Miller*** conducted a targeting workshop together with the Siguiri Exploration department. The exercise was conducted over the entire Siguiri tenements, but with a greater focus on Block1.
The workshop leaders used a mineral systems approach for identifying and ranking targets. Targets were evaluated and compared to existing targets. This evaluation involved assessment of soil anomalies and existing drilling. This confirms that in many cases the targets correlated with existing and on-going exploration targets and the deposits (**Figure 61**). The use of the mineral system approach validated existing targets, and it also highlighted past targets that ranked highly in the mineral systems approach and that are currently under explored. In particular new targets were delineated under transported cover that may be blind to standard soil sampling.

The proposed targeting criteria are used to define the targeting model and to assess the Siguiri district, and this will avoid expenditure and time consuming. Each of the critical processes constituent processes and mappable criteria or proxies are reviewed and described below.

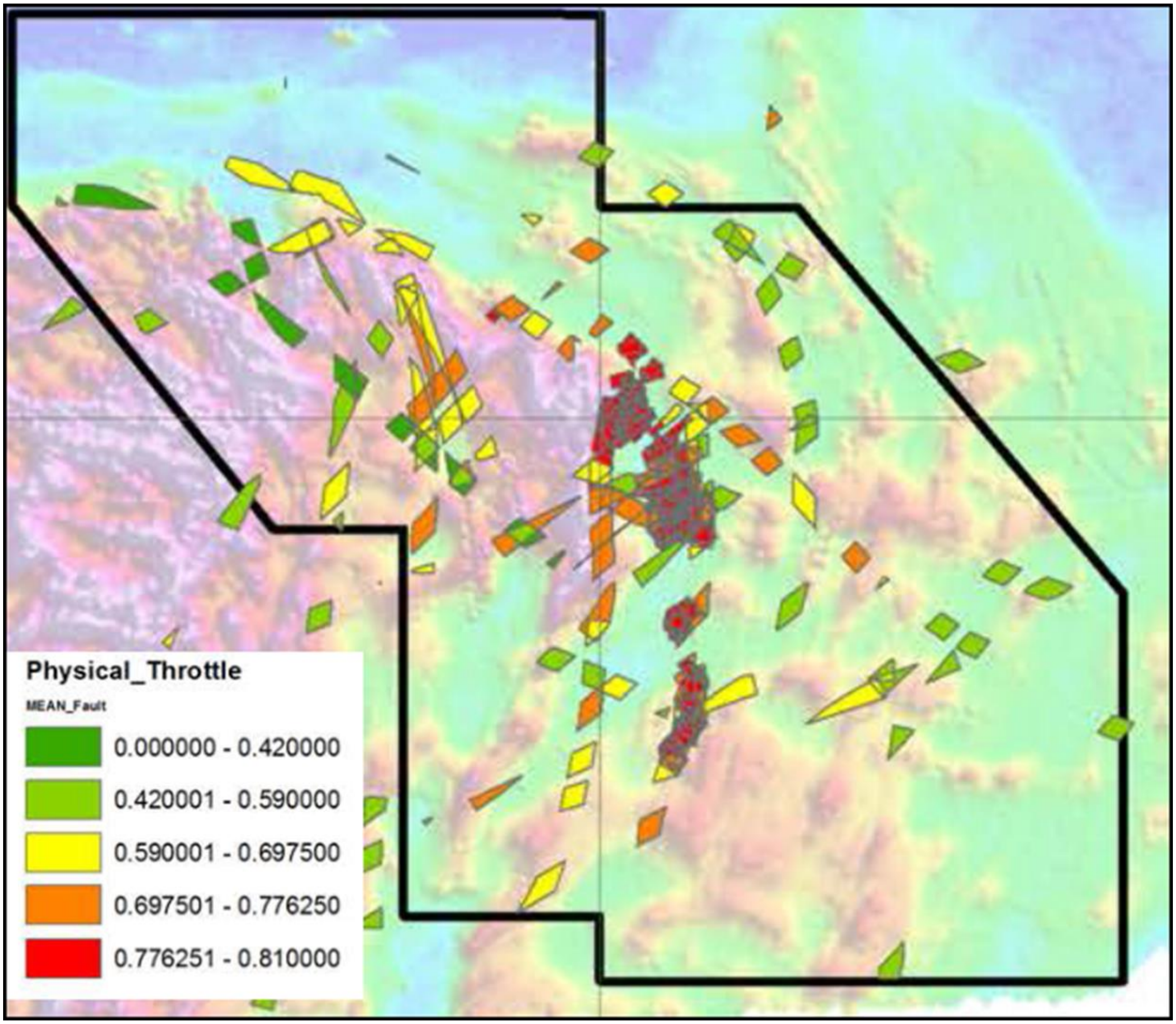

Figure 61: Summarize target (Professors Nicolas Thébaud and John Miller, June 2014).

9.6.1 Target ranking

Interpreting the subjective values attributed to each critical element; the final rank was established for the generated targets base on the techniques described on the mineral approach.

- P1 = Source
- P2 = Active pathways

- P3 = Physical Throttle
- P4 = Chemical and Physical Scrubber

Table 16: Table summarising the attributes P1 to P4 for targets X, Y and Z. The highest ranking is attributed to Target X.

Target Name	P1	P2	P3	P4	Ptotal
Target X	1	0.8	0.7	0.9	0.50
Target Y	0.5	0.8	0.9	0.9	0.32
Target Z	0.5	0.8	0.9	0.5	0.18

9.6.2 Target evaluation

The use of the mineral system approach permitted the definition of some targets, and this includes explore or unexplored and untested to date. In particular new targets were delineated under transported cover that may be blind to standard soil or termite mound sampling. Using ARC-GIS to create shape file is very helpful data combination and interpretation.

The mineral systems approach has proved reliable in that where mineralised areas are known to exist at Siguiri and where these were re-assessed using this mineral systems approach, these particular targets received a high ranking.

The observation made to appreciate the methods is that some high-rank targets generated are already associated with deposits and as such are supporting the validity of the targeting model applied to the area. Easy to review if each individual generated target is in within regards to the existing drilling, soil anomaly, and geological knowledge.

In addition for each target a follow up status can established; and required, the work program can recommended such as more field investigation (where outcrop condition permitted sampling and mapping) and also exploration drilling.

Due to the lack of outcrop in many areas, a particular importance in remote sensing are the geophysical data as well as the satellite imagery need to be made. Artisanal mining activities are often a good indication of gold in the area. Also consider the target close the lithological contact and along the structure.

Chapter 10 : Conclusions

The completion of a Landform and Regolith map, in an early exploration program, can greatly assist all aspects of the exploration program, and largely reduces the 'luck factor' of finding ore bodies. Failure to understand the regolith terrain can result in inappropriate sampling, interpretation and ultimate decisions for progressing or terminating a project.

Due to the laterite development over most of the Siguiri district the geological map strongly relies on the interpretation of potential field data such as aeromagnetic data (AEM). As a result, the geological interpretation and associated localisation of lithostratigraphic contacts and/or faults are associated with an important level uncertainty. This uncertainty may prove to be an important factor to be considered prior to drill-testing a target as the model applied are essentially focus on structural intersections and structure/stratigraphic intersections (i.e. faults with faults, faults with stratigraphy), one option for target drill-holes during initial stage of drilling campaign is to define major stratigraphic boundaries and/or fault location for targeting adjustment.

In regolith-dominated terrains, the effects of weathering and evolution cannot be disregarded during the planning and interpretation of mineral exploration programs. Landform and regolith mapping is a fundamental tool allowing the exploration geologists to take into account the "regolith factor" at all phases of the work.

The effects of chemical and physical dispersion, resulting in displaced or transported anomalies, can be incorporated into any interpretation. Follow-up sampling can therefore be directed to all probable source areas. High assays are not always anomalies; structural trends, lithological contacts and preferential lithologies should be considered as vectors for targeting.

In an exploration stage, regolith mapping is an integral part of the program to ensure that most appropriate techniques are applied and most logical conclusions are reached before the completion or closure of the project. Exploration can proceed without a landform and regolith mapping, but if we want to reduce the luck factor, and localize the mineralisation missed out by previous generations, then regolith mapping and soil geochemistry are a very necessary process for regional target generation.

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