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Some Aspects of the Geology and Environmental Impact Assessment of a Proposed Gold Mining Site X in Borgu Local Government Area of Niger State, Nigeria

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Abstract

Proposed Gold mining Site X is located on Nigerian basement rocks in the Borgu Local Government Area of Niger State. The geology and geochemistry of the rock formations in a mining site contribute significantly to understanding the economics of the mineral deposits and the impacts on the environment, particularly the surface and groundwater viz-a-viz the health of the community inhabitants, soil, vegetation and other salient parameters, including weather conditions and socio-economy of the people. The geology and geochemistry of rock units, soils, stream sediments and water of Site X indicate rich deposits of Gold attractive for exploitation, concentrated in three delineated portions of the site as "Concentrates" A, B, C. With these results and impending mining of the gold deposits, some aspects of the environmental impact of mining the gold resources have been studied and reported herein. This is to ensure successful mining operations with minimum negative impacts on the surrounding environment when the applicant mining company obtains a mining lease from the Mining Cadastre Office. The lessons to learn are that a successful economic development depends on rational use of natural resources and on reducing as far as possible the adverse environmental and social impacts of developmental projects.

Keywords: Gold; mining; degradation; reclamation; social impacts.

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1. Introduction

Civilization as we know it today would simply not exist without steel, oil, and hundreds more metals and fuels. Unfortunately, there's a terrible price to be paid for the wrenching of these materials from the ground, and payment has been deferred for too long. Mineral exploration, mining and processing come along with several environmental impacts including wildlife and fisheries habitat loss, changes in water quality, sedimentation, toxins in tailings ponds and effluent, acid generation, dust, and slope. An EIA study was carried out on Site X located in Borgu Local Area of Niger State (Nigeria) to ensure successful mining operations with minimum negative impacts on the surrounding environment when the applicant mining company obtains a mining lease from the Mining Cadastre Office. This is because a successful economic development depends on rational use of natural resources and on reducing as far as possible the adverse environmental and social impacts of developmental projects. The geology and geochemistry of the rock formations in a proposed mining site contribute significantly to understanding the economics of the mineral deposits and the impacts on the environment, particularly the surface and groundwater viz-a-viz the health of the community inhabitants, soil, vegetation and other salient parameters, including weather conditions and socio-economy of the people.

The proposed Gold mining at Site X is envisaged to lead to an increase in the income of the host communities and other surrounding communities through direct and indirect employment opportunities, thereby enhancing the socio-economic activities of the area. It will lead to increment in social services and will open up new market opportunities for the communities, as well as improve exchange of regional and inter-state trade and services. The project will also positively impact on the revenue generation of the area through local taxation and other levies. It will further attract private and government investments in industries and infrastructural development through the road infrastructures that will be developed. It is envisaged that the benefits of the mines operations shall have a multiplier effect on socio-economic activities of the locality and even the region.

2. Study Area

The study area, Site X, is located near New Bussa town in Niger State, Nigeria (Fig. 1). The site has obtained a previous exploration licence (EL) and it is proceeding to application for a mining lease, thus will need the full complement of feasibility and EIA studies including an Environmental Protection and Remediation Plan (EPRP) and a Community Development Agreement document. The project forecasts large scale, highly mechanized mining activities concentrated on extracting mainly Gold (but also other associated economic minerals) from the geological terrains in the area.

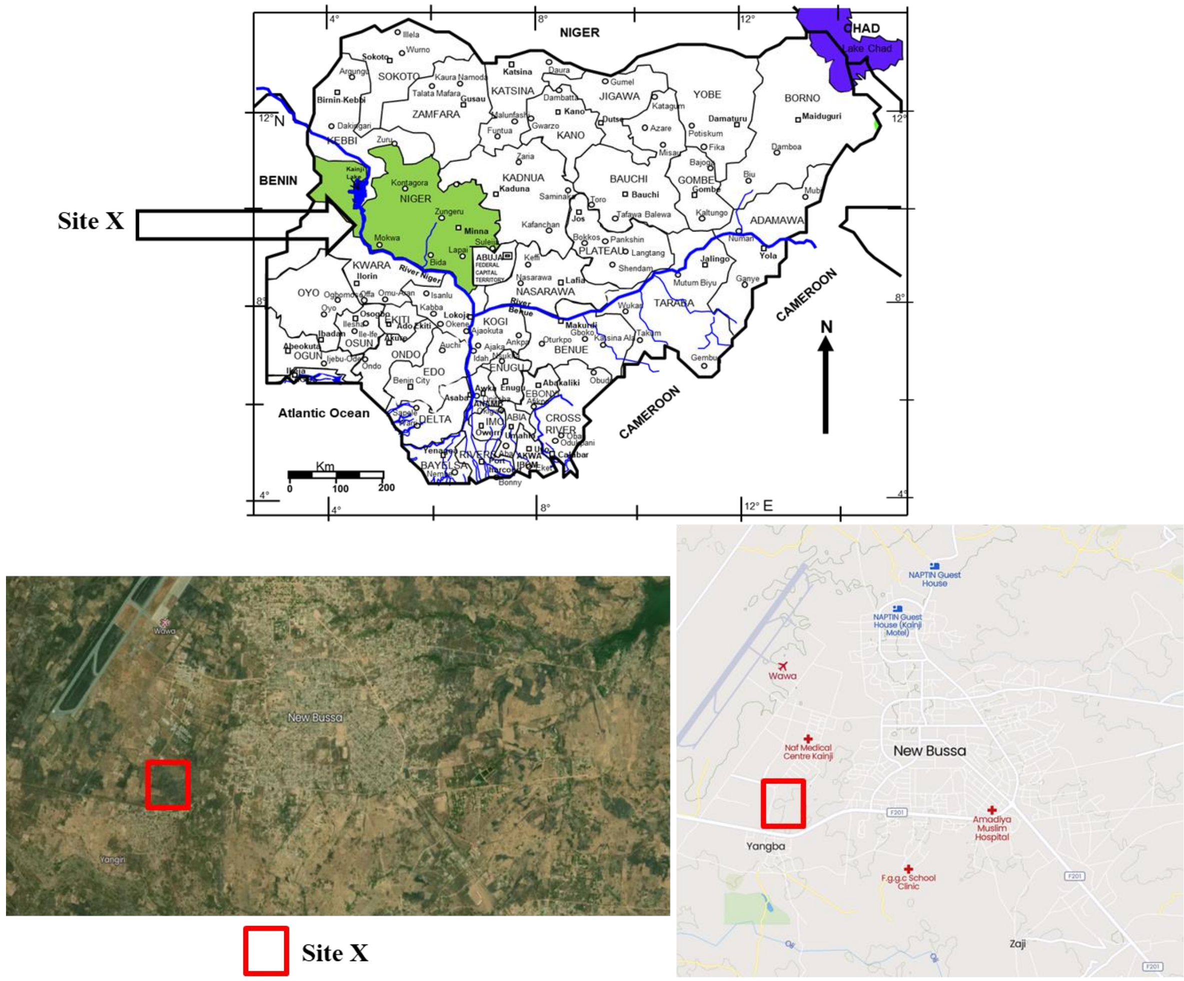

Figure 1: Location of proposed mining Site X in Borgu Local Government Area of Niger State

3. Legal and Regulatory Framework for Environmental Protection in Nigeria

In order to achieve sustainable development and live in harmony with nature, environmental protection and control has now become an integral part of laws/regulations/policies promulgated at international, national and state/local government levels. Also, responsible corporate organizations formulate policies that enable them establish and operate sound environmental management systems. The relevant policies, regulations, laws and guidelines that affect mining projects are highlighted in the National Policy on Environment and the National Guidelines and Standards for Environmental Pollution Control in Nigeria [1], Management of Hazardous and Solid Wastes Regulation and the Environmental Impact Assessment Act [2].

4. Methods of Study

Because the geology and geochemistry of the rocks, water, soil and stream sediments have great impacts on the physical and chemical environments, the study began with a geological mapping of Site X. Samples collected from the geological materials and other associated media (water, soil and stream sediments) were subjected to geochemical analysis using the XRF and the Fire Assay analytical methods. The results obtained were juxtaposed against other environmental impact assessment parameters that may have geological correlations (soil, water, vegetation, etc). Other salient EIA data were generated during rainy and dry seasons and interpreted in the direction of obtaining mitigation and remediation. The EIA was duly registered with the Federal Ministry of Environment and protocols thereof adhered to.

5. Results and Discussion

Geology

Geological mapping shows that rocks within Site X comprise phyllitic schist, pegmatite-QF (rich in quartz and feldspar) and pegmatite-QFM (mostly the veins rich in quartz, feldspar and mica), granite gneiss, amphibolitic schist, banded gneiss and migmatite gneiss, generally trending in the NW-SE direction. Some iron ore deposits were also mapped. Although rocks of the Nigerian basement complex including the schist belts trend generally NE-SW [3, 4, 5], the local geology of Site X area is imprinted by rocks that trend NW-SE (Fig. 2). This could be related to sets of strike faults characterized by a dextral sense of movement and limited to the map in spatial scope. The schist orientation in the area is NNE-SSW on which the other rocks crisscross as discordant units, may be on a major fault. Site X is within the region of the Migmatite-Gneiss and undifferentiated basement encompassing Older Granites and the Zuru Schist Belt, thus attesting to a potentially highly mineralized zone, especially for Gold [6].

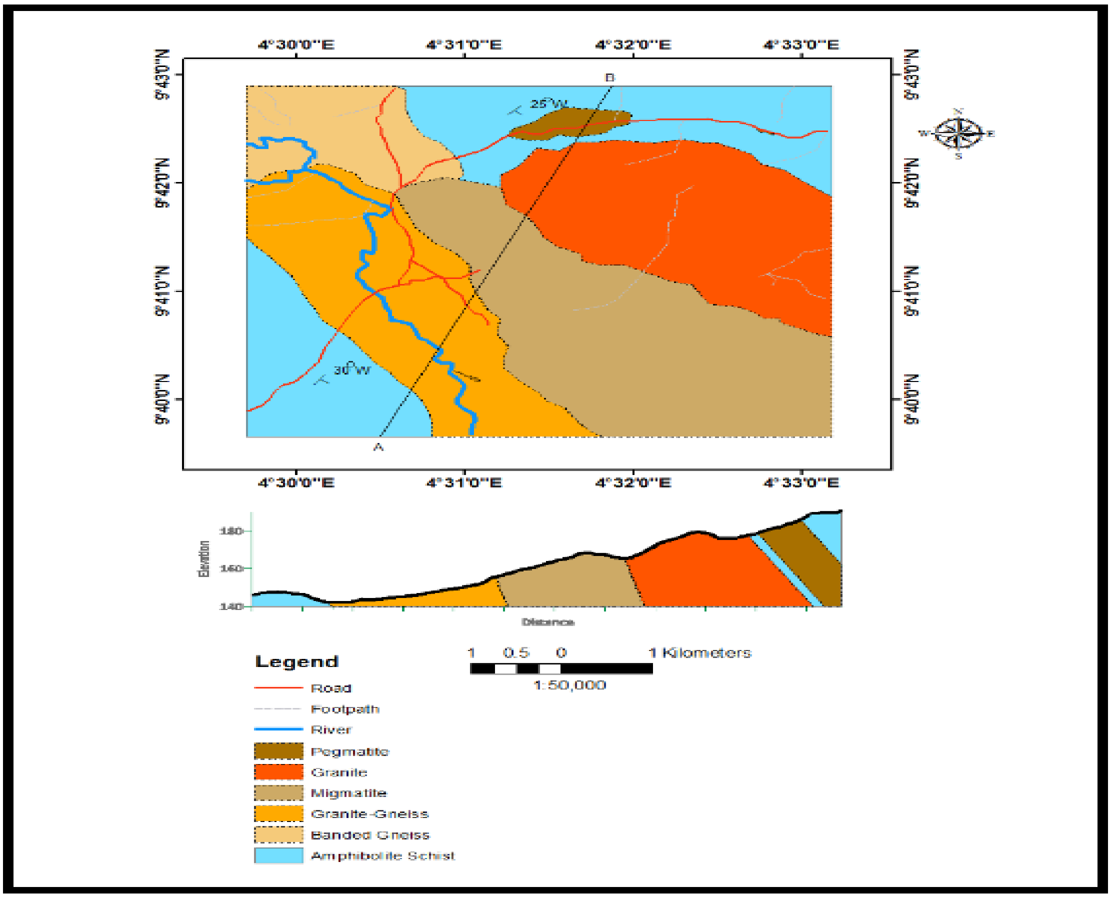

Figure 2: Geological map of Site X in Borgu Local Government Area of Niger State.

Geochemistry

The geochemical results plotted against the coordinates enabled the identification of three Gold concentrate zones (A, B, C) located in the southwest corner, central axis and northeast corner, respectively (Fig. 3). The correlation of the Gold contents against other elements shows different trends, some of which could be used as pathfinders for the gold deposits (Figs. 4-9). Although the total Gold (Au) content in ppm is highest in the rocks than in the soils and stream sediments, there is no particular preference of the individual Gold values to any medium (rock, soil, stream sediments). While the lowest contents of Gold were recorded in the soil samples, one soil sample equally recorded the highest Gold content. The trends of the concentrates individually tally with local geological trend of the project area (NW-SE) while the group (all three concentrate) adopt a configuration aligned to the general structural trend of the Nigerian basement (NE-SW) showing that the gold mineralization are controlled by the general structural trend of the host rocks, although the trend of the central concentrate (deposit) is more in the N-S direction slightly disoriented from the general SW-NE trend.

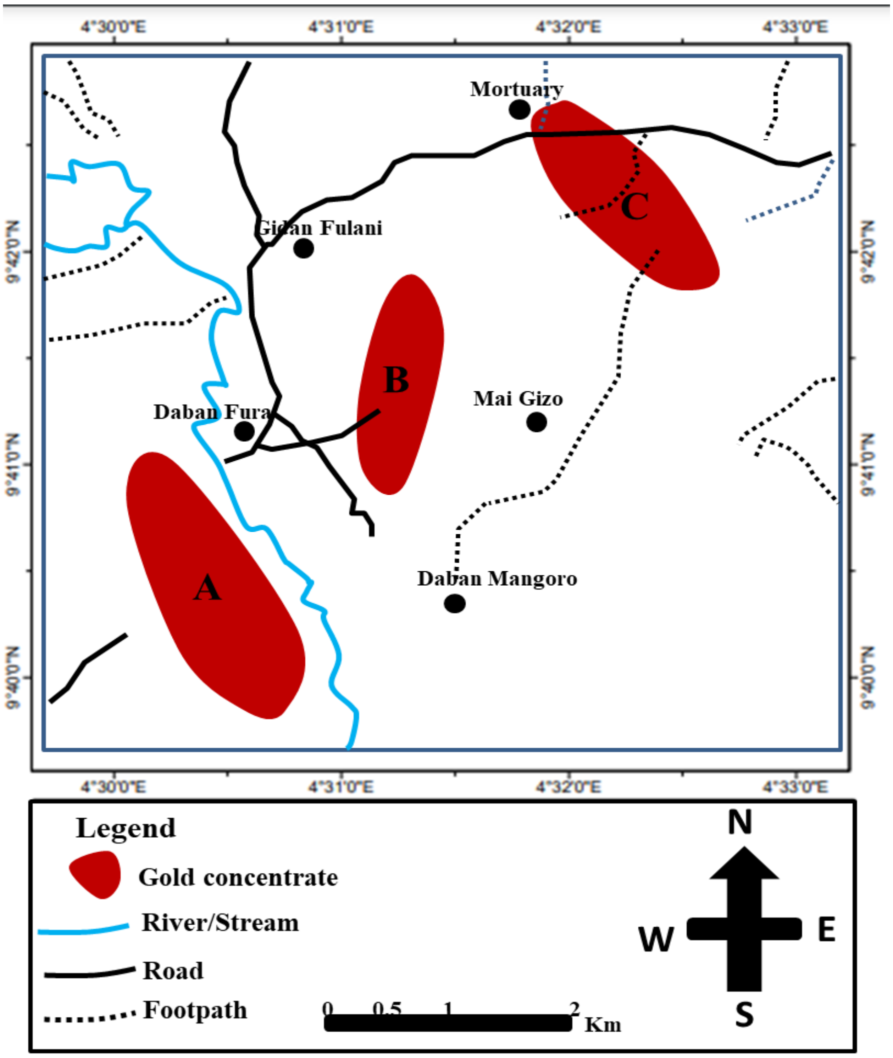

Figure 3: Geochemical results plotted against the coordinates enabled the identification of three Gold concentrate zones (A, B, C) located in the southwest corner, central axis and northeast corner, respectively.

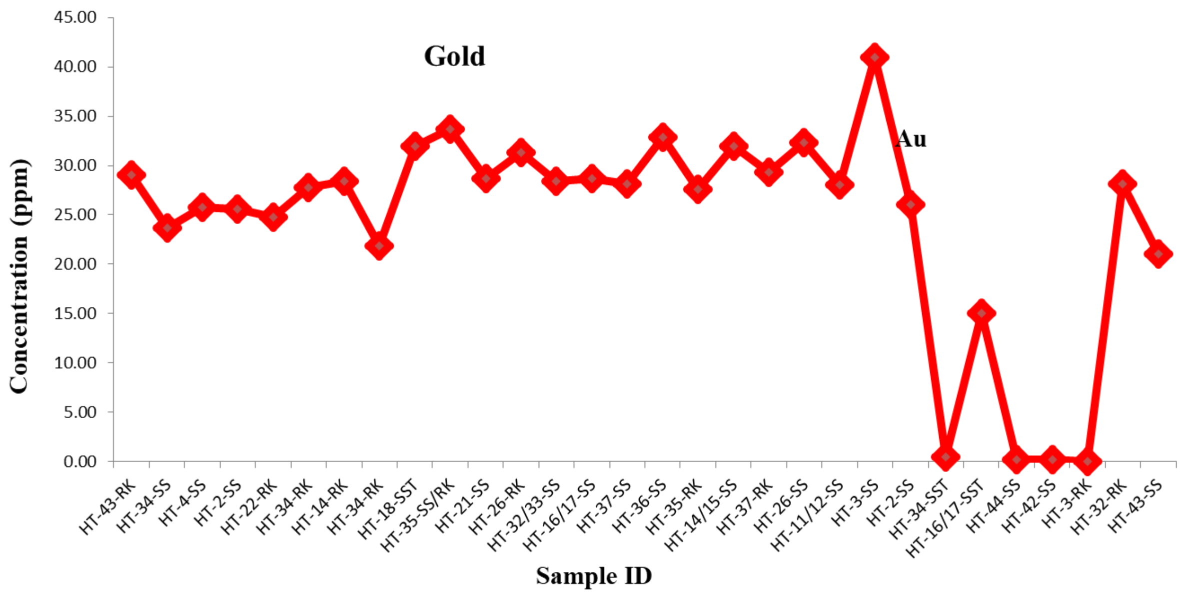

Figure 4: Gold content (ppm) distribution in 30 samples from the project area. While the lowest contents of Gold were recorded in the soil samples, one soil sample (HT-3-SS) equally recorded the highest Gold content.

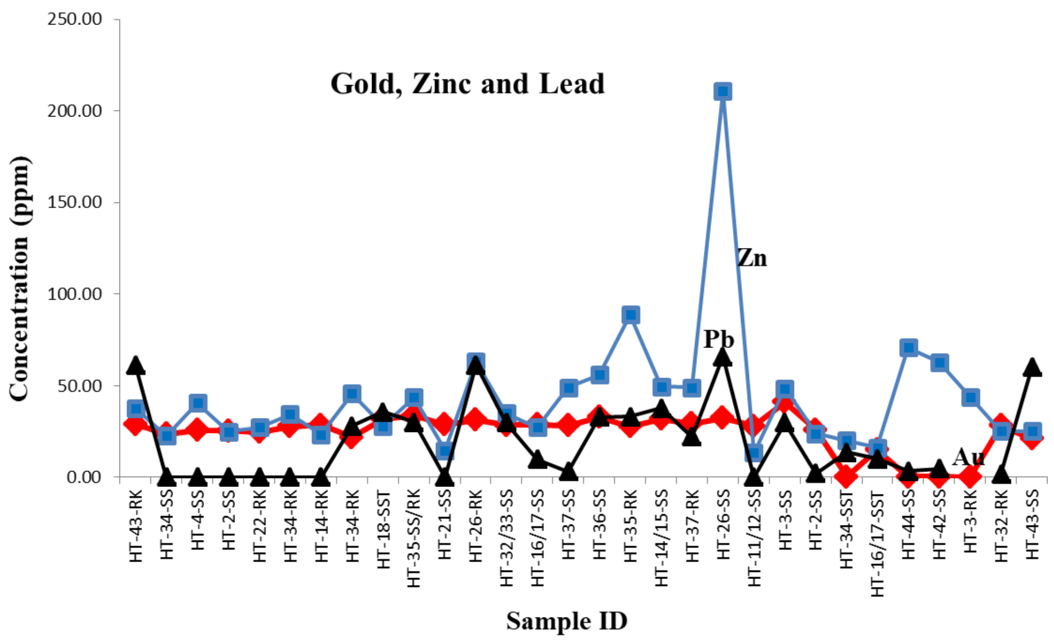

Figure 5: Correlation of Gold content against Zinc and Lead shows no particular correlative trend. However the Lead allows to some extent a correlation to the Gold content and may serve as a limited pathfinder.

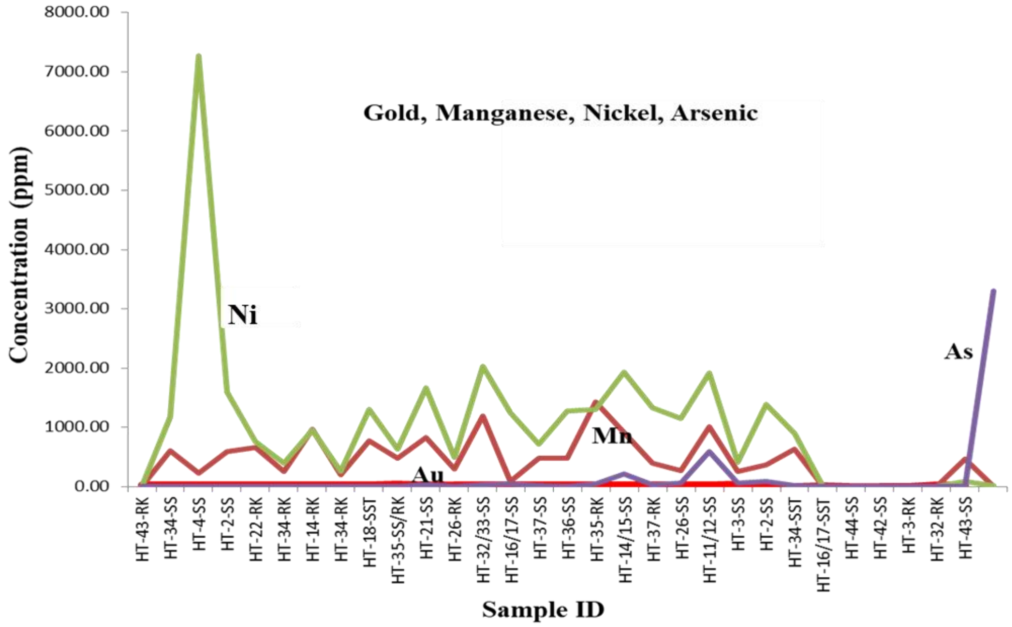

Figure 6: Correlated against Manganese, Nickel and Arsenic, the Gold is reduced to insignificance. Sample HT-4-SS, not within the concentrates, is heavily loaded with Nickel while sample HT-43-SS within the C concentrate area is loaded with Arsenic.

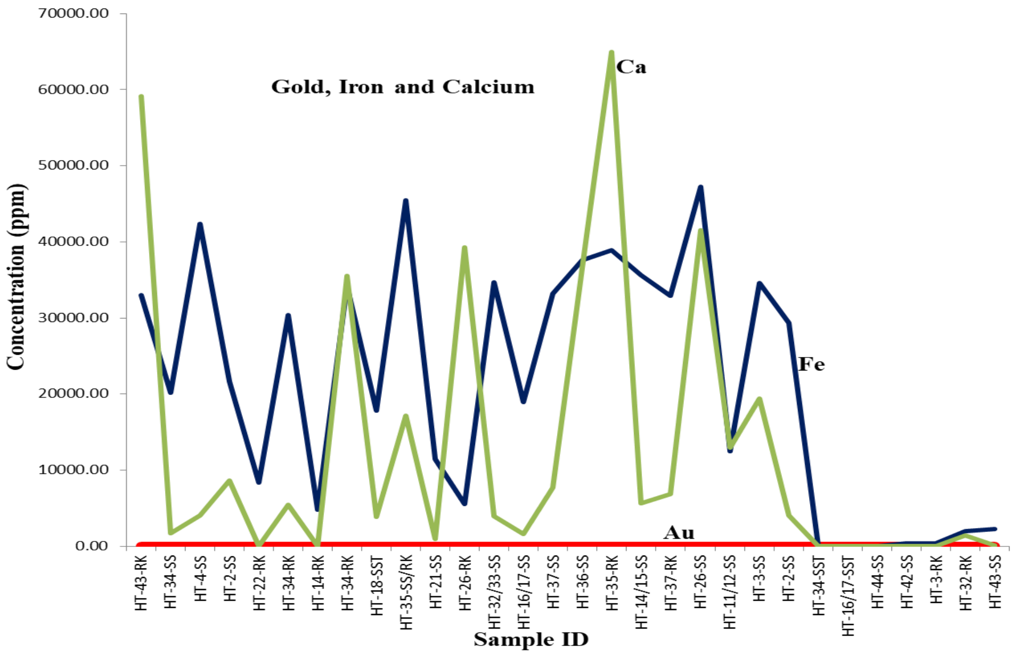

Figure 7: Correlated against the major elements of Iron and Calcium, no correlation is derivable and Gold pales to insignificance

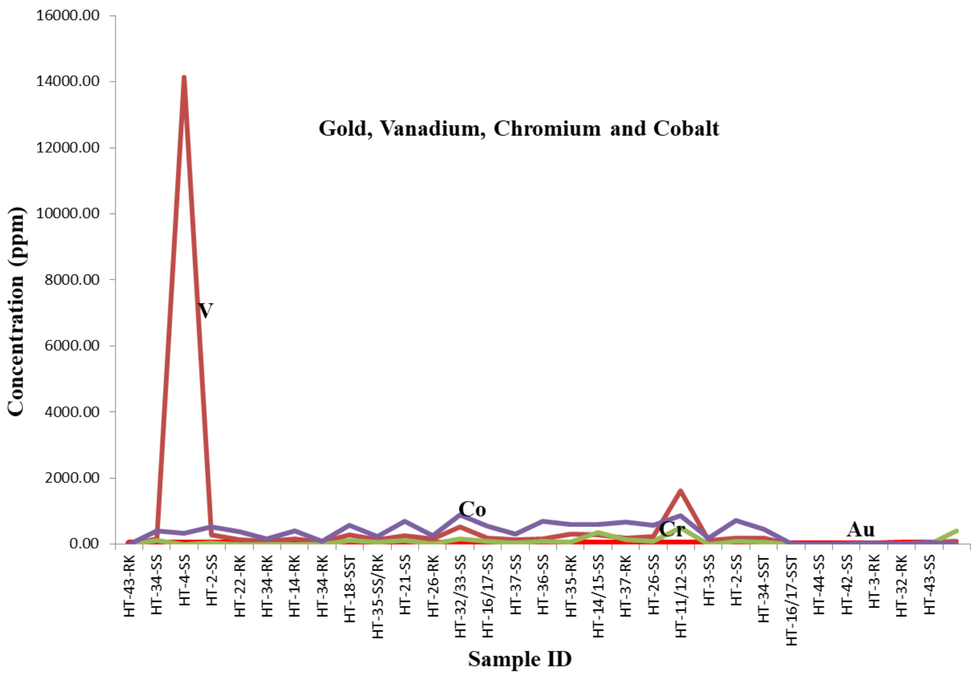

Figure 8: Correlated against the Vanadium, Chromium and Cobalt, no correlation is derivable and Gold pales to insignificance. Sample HT-4-SS, not within the concentrates, is loaded with Vanadium.

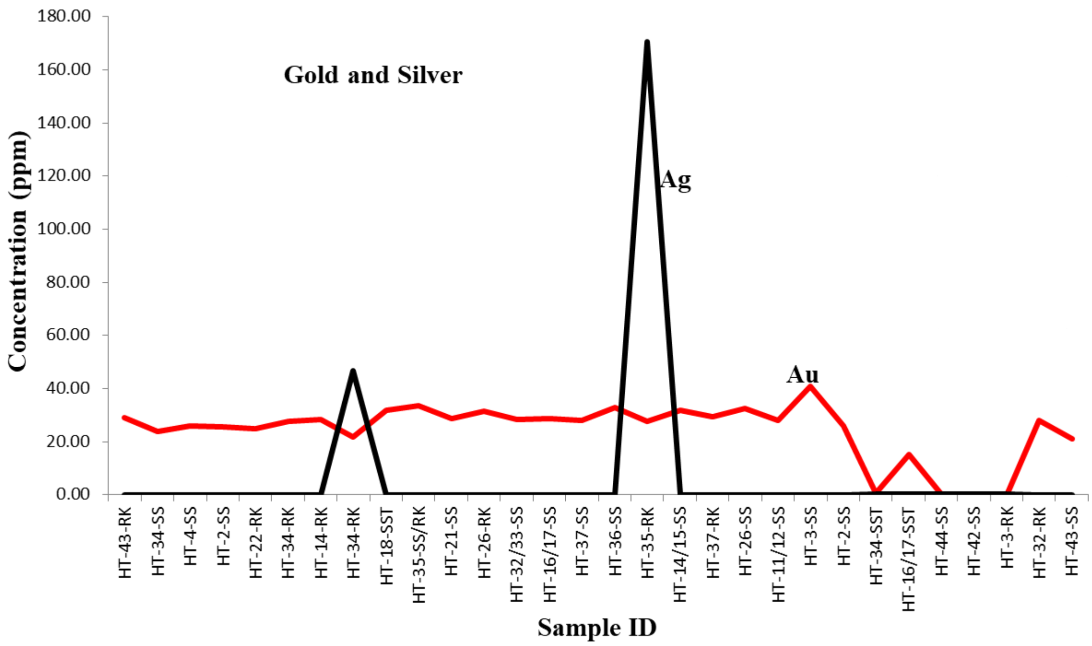

Figure 9: Gold correlated against Silver shows no particular correlation. Samples HT-34-RK within concentrate A and HT-35-RK within concentrate B are moderately and highly, respectively, loaded with Silver.

Hydrology and Hydrogeology

The major rivers and streams within the project area include River Olei (tributary of River Niger), Koniji Stream, Kyakasika seasonal stream, Nasarawa-Korov Stream, Koshkema Stream, Kinyene Stream, Shange Stream, Rafin Kala Stream, and of course, River Niger. These water bodies are seasonal except for River Niger. The main water body within the project area is the River Olei which is drained by the River Niger. Table 1 shows the hydrological characteristics of some of the water bodies within and around Site X.

Table 1: Hydrological properties of some rivers within and around the study area

Water Body	**Width (m)**	**Depth (m)**	**Variation in level (m)**	**Flow rate (m/s)**	**Discharge rate (m^3/s)**
Nasarawa Koro Stream	15	1.0	0.28	0.021	0.32
River Olei	60	0.15	0.52	0.051	0.46
River Niger	950 1150	2.8 7.3	4.5	0.516 0.49	1372.56 4113.6

Air Temperature

Air temperature values for the project area are generally slightly higher for the dry season months (33.3-36.6^{0}C) than the wet season months (30.0-33.1^{0}C). Nevertheless, temperature is uniformly high throughout the year with a small monthly range. The highest mean temperature values occur in the month of March and April at the peak of the dry season and the onset of the rainy season, while the lowest occur in the month of December at the peak of the harmattan season. During the field studies the temperatures recorded at various sampling locations within the study area ranged from 21.4 – 39.0^{0}C and fall within the historical range of temperatures for the area. The dew point temperature ranged from 21.8 – 29.5^{0}C during the field studies. Field observation suggests that on a diurnal basis, maximum temperature occurs between 1300 and 1500h while minimum temperature occurs between 0100 and 0600h.

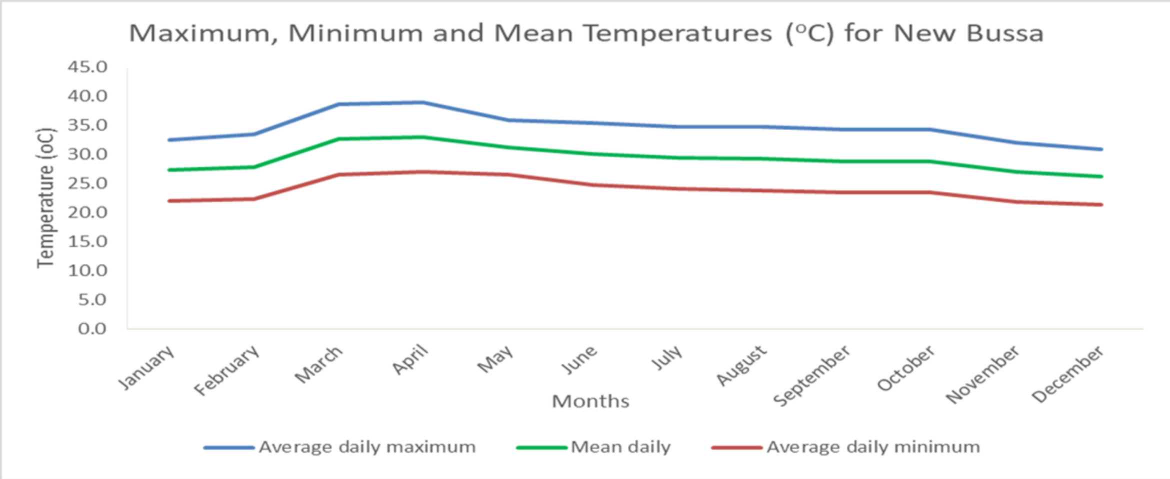

Figure 10: Maximum, minimum, and mean temperatures (^{o}C) for Site X

Relative Humidity

Mean monthly relative humidity is generally low with no month experiencing values greater than 85% (Table 3). As expected, mean monthly relative humidity values are slightly high for the wet season months (June to October) with the highest values occurring within the months of June and September (Fig. 10). This is when the influence of the moisture-laden southwestern directed wind is greatest.

Table 3: Mean monthly relative humidity (%) and mean monthly total rainfall (mm) for Site X

Month	**Mean Monthly Minimum Relative Humidity (%)**	**Mean Monthly Maximum Relative Humidity (%)**	**Mean Monthly Total Rainfall (mm)**
January	62	53	00.0
February	59	41	00.0
March	63	57	51.5
April	75	59	102.3
May	79	55	154.4
June	79	69	154.4
July	76	56	179.8
August	72	62	178.8
September	84	66	203.7
October	78	58	126.0
November	76	54	27.4
December	68	42	00.0
Mean	72.6	56.0	98.4

Source: NIMET, Abuja

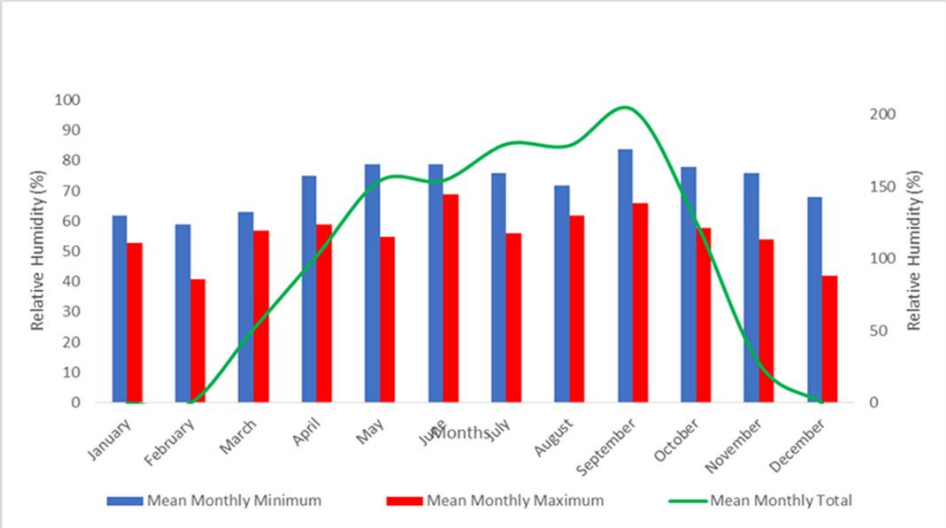

Figure 10: Average relative humidity and total average rainfall amount within and around Site X.

During the field monitoring, daily relative humidity of 55-90% was recorded for wet season and 50-72% for dry season. Maximum relative humidity values generally occurred between 0700h and 0900h while minimum relative humidity values were recorded between 1000h and 1600h.

Soils (Chemical Properties)

The chemical properties of soils of at Site X are acidic to slightly alkaline (pH 3.8 – 7.6). There was no distinct trend in pH values for the wet and dry seasons. The electrical conductivity values were low (15.3 – 270µs/cm) indicating that the study area is within the fresh water zone. The carbon concentration (0.42 – 4.19%) were adequate to high compared to the critical level of 1%. The soils at the project area contain high organic carbon due mainly to the denser vegetation. Similarly, the dry season recorded higher organic matter content compared to the wet season due to the fact that during the dry season, most of the organic carbon remained undecomposed as a result of low moisture content of the soils.

Heavy metals

The results of the heavy metals analysed show that all the metals occurred in trace levels or very minute quantities far below recommended limits set by DPR/FMENV. The values were lower than that reported for Nigerian inland and coastal waters [7, 8, 9].

Total Hydrocarbon (THC)

The total hydrocarbon values reported were quite low in the sampling stations. It fluctuated between 0.15mg/l and 172.8mg/l. These levels are generally lower than recommended limits for inland waters in Nigeria, except at some isolated sampling stations where increased human activities have introduced various sources of organic materials. Nonetheless they are not from petrogenic sources.

Aquifer Depth-Fluctuation and Flow Direction

The depth of groundwater in the area is dependent on the topography, climate, thickness, and depth of aquifer at a certain point in time. The aquifers lack recharge during dry season due to lack of rain and capacity utilization of groundwater, which brings about fluctuation of depth in groundwater level. As for the deep-seated weathered basement aquifer, the depth to the water table ranges from 30- 70m with water level of 5m in the wet season. In the shallow overburden aquifer the water level during the wet season is between the surface in lowland areas and about 2- 5m in highland areas.

Aquifer Properties

The porosity of the aquifers of the study area varies from the highly porous and permeable overburden to the less porous and permeable weathered basement rock. The weathered migmatites are rich in clay minerals hence less permeable. Permeability of different types of soils by Black [[10] gives the soil in the weathered basement aquifer a coefficient of permeability value of 100- 10-2 gal/day (poor) while that of the overburden ranges from 102-104 gal/day (Good) the deeper fractured rock aquifer (if so confirmed) is characterized by high permeability and high flow rate. The two main types of aquifer in the study area are the weathered basement and the joint fractured basement aquifer with the latter sometimes occurring below the former. Areas such as this hold more potential for ground water than areas with only weathered basement.

Aquifer Recharge

The main source of recharge for the aquifer in the area is rainwater. The amount of rainfall within the region is high and lies between 900 and 1,200mm per annum. The rate of infiltration is also quite high due to the porous nature of the overburden. Aquifer lateral recharge also results from the difference in gradient of groundwater.

Ethnic Composition

A number of ethnic groups exist within the project area. Bussa is the single largest ethnic group and is followed by Kambari, Hausa, Fulani, Yoruba and Nupe in that order respectively. It is worthy to note that some ethnic groups exist in these settlements though not reported above. This is due to the fact that they are not significant in terms of population.

6. Lessons to Learn

The results of the study have led to development of mitigation, remediation, adaptation, reclamation, monitoring and decommissioning plans and measures. Mitigation includes avoiding, minimizing, rectifying, and reducing impacts. These regulations also provide for compensation by providing substitute resources or environments. The applicant company has built into its proposed project many mitigation measures that have been taken into account in assessing the environmental consequences of the alternatives. Reclamation is to return disturbed land to the designated post-mining land use, as defined by regulation and standards, public recreation and wildlife habitats. The reclamation plan called for re-establishing wildlife habitat within 5 to 15 years by stimulating growth of early succession vegetation. The monitoring plan has been developed for the purpose of ensuring that the project operations are in compliance with national environmental and social standards. This plan shall guide the evaluation of environmental effects of the project. It also provides the parameters for assessments during periodic Environmental Audit of the mines. Prior to commencing removal of items of equipment, the contractor shall ensure that the equipment has been approved for decommissioning. Thereafter consultations shall be held for the decision regarding the disposal of the equipment after removal. Detailed site surveys are expected to be carried out on the condition of the soil. Any polluted soil shall be treated in-situ or removed from the site and treated/disposed of safely and in an environmentally acceptable manner. A detailed EPRP has been developed for the proposed mining operation at Site X in line with the Mining Act of the Federal Republic of Nigeria. EPRP outlines practical procedures required for all activities of the project and personnel (i.e., employees, contractors and suppliers) to reduce or eliminate the potential environmental effects associated with the development and operational phases as well as post operational phase of the mining site.

7. Conclusions

The geology and geochemistry of the rock formations in a proposed mining site have been found to contribute significantly to understanding the economics of the mineral deposits and the impacts on the environment, particularly the surface and groundwater viz-a-viz the health of the community inhabitants, soil, vegetation and other variables in environmental impact assessment studies. The geological and geochemical studies of site under investigation indicate rich deposits of Gold attractive for exploitation, concentrated in three delineated portions of the site as “Concentrates” A, B, C. With these results and impending mining of the Gold deposits, some aspects of the environmental impact of mining the gold resources have been evaluated. The mining Site X is located in Borgu Local Area of Niger State (Nigeria). The proposed Gold mining at Site X is envisaged to lead to an increase in the income of the host communities and other surrounding communities through direct and indirect employment opportunities, thereby enhancing the socio-economic activities of the area. The site has obtained a previous exploration licence (EL) and it is proceeding to application for a mining lease, thus will need the full complement of feasibility and EIA studies including an Environmental Protection and Remediation Plan (EPRP) and a Community Development Agreement document.

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Photo Annexure

Figure 11

Visit of EIA study team to the National Wild Life Park, New Bussa (June 2021) and some endangered animal species demonstrated at the National Wild Life Park, New Bussa (June 2021)