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# REVIEW ARTICLE

## ECONOMIC POTENTIAL OF AINAMOI BAUXITE MINERAL DEPOSIT, KERICHO COUNTY, KENYA

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**ABSTRACT**

Minerals, together with exploration methods that are based on prior geological knowledge and practical concepts, continue to influence infrastructure development. Field geological mapping can be followed by applying geophysical survey investigations, geochemical analytical techniques, or drilling methods to unravel the envisaged details. Indeed, mineral mapping begins with analyzing historical information, geological mapping, field observations, and collecting field samples for further investigations under laboratory conditions. Such investigations were conducted in the Ainamoi region of Kericho County, Kenya. Anomalies with substantial bauxite mineralization were discovered during the investigations, as the geochemical outcomes revealed. The study investigated the economic potential of bauxite mineral deposits (Aluminum ore) with respect to concentration per acre of land, depth/height of the resource, and percentage of the ore that is endowed in the evaluated area. The evaluation revealed that the bauxite deposit had an average thickness of 2 m per hectare of land in most localities. It was found that the evaluated area was economically viable and favorable for the exploitation of the natural resource for cement manufacturing.



# INTRODUCTION

The crust of the Earth is comprised of 8.3% aluminum, however, due to its strong affinity for oxygen and silicon, it amalgamates with other metallic cations to produce silicate minerals such as ruby ($AlO2$). In bauxite ore, aluminum is present in the gibbsite mineral, ($Al(OH)3$. The gibbsite often occurs together with boehmite ($\gamma$-$AlO(OH)$) and diaspore ($\alpha$-$AlO(OH)$), mixed with the two iron oxides i.e. goethite ($FeO(OH)$). The silicate mineral commonly found in clay minerals is kaolinite ($Al2Si2O5(OH)4$, whereas secondary minerals that are typically present in small quantities are anatase ($TiO2$) and ilmenite ($FeTiO3$ or $FeO.TiO2$). The color of bauxite ore is reddish-brown, white, or tan, with a dull luster. Alumina (86%) is the primary mineral source of aluminum metal, which is extracted through mineral processing techniques. In practice, it takes between four and seven tons of bauxite ore to produce two tons of alumina, producing around one ton of aluminum metal. Bauxite has various uses, especially non-metallurgical ones, despite being used in the manufacturing of metallic aluminum. According to Goncalves *et al*. (2009), the applications encompass furnace linings as a refractory material (31%), the production of abrasive materials (24%), the production of chemical products (16%), and the utilization in the cement industry (18%). According to the United States Geological Survey, Mineral Commodity Summaries of January 2020, the world resources for bauxite were estimated to range from 55 billion to 75 billion tons. The resources were distributed among Africa (32%), Oceania (23%), South America and the Caribbean (21%), Asia (18%), and other regions (6%). The reserves in Africa were reported to be held mainly by Ghana, which continues to rank third among the world's top five countries in bauxite mining on the global platform.

**Location and Size of the Study Area:** The study area is located in the Ainamoi Constituency in Kericho County. The County is one of the 14 counties within the Rift Valley Region of Kenya.

It lies between longitudes 35º 02' and 35º 40' East, and between the Equator to the north and latitude 0o 23' to the south. The county borders Uasin Gishu County to the north, Baringo County to the northeast, Nandi to the northwest, Nakuru County to the east, and Bomet County to the south. It is bordered by Nyamira and Homa Bay counties in the southwest and Kisumu County in the west (Fig.1.1).

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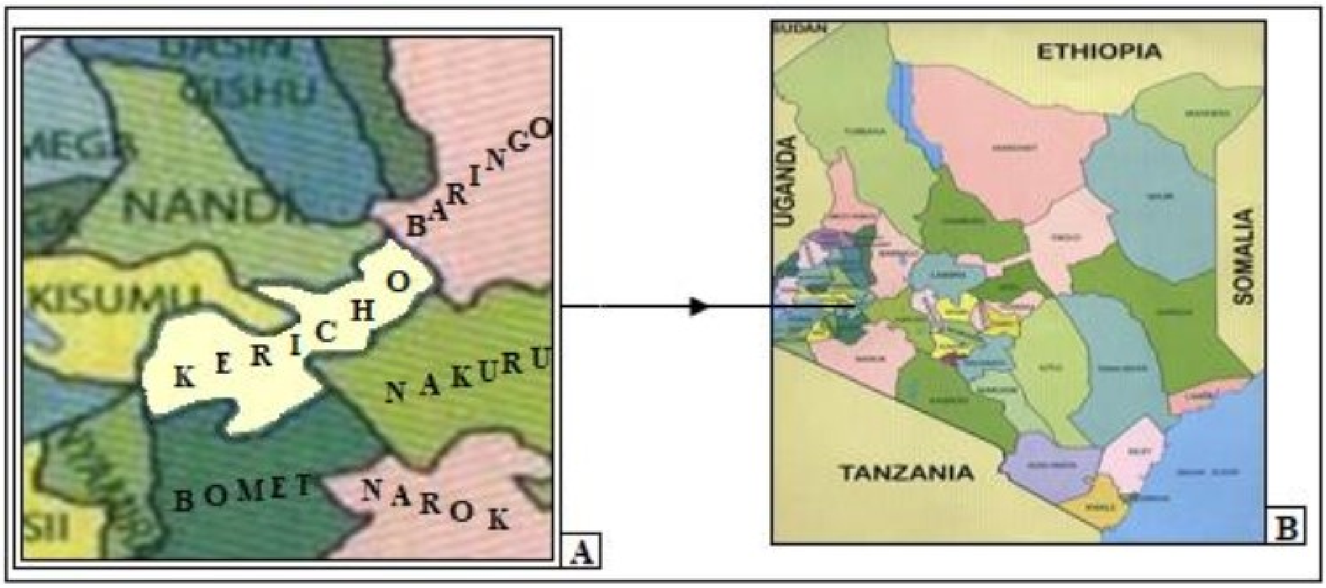


**Fig.1.1. Location of Kericho County (A) and Counties of Kenya (B)**

The county has a total area of 2,479 square kilometers. The study area is specifically located within Poiywek Sub-location, Ainamoi Ward, Ainamoi Constituency, Kericho County. It is approximately 15 kilometers north of Kericho Town and approximately 6 kilometers north of Ainamoi Trading Centre (Fig.1.2).

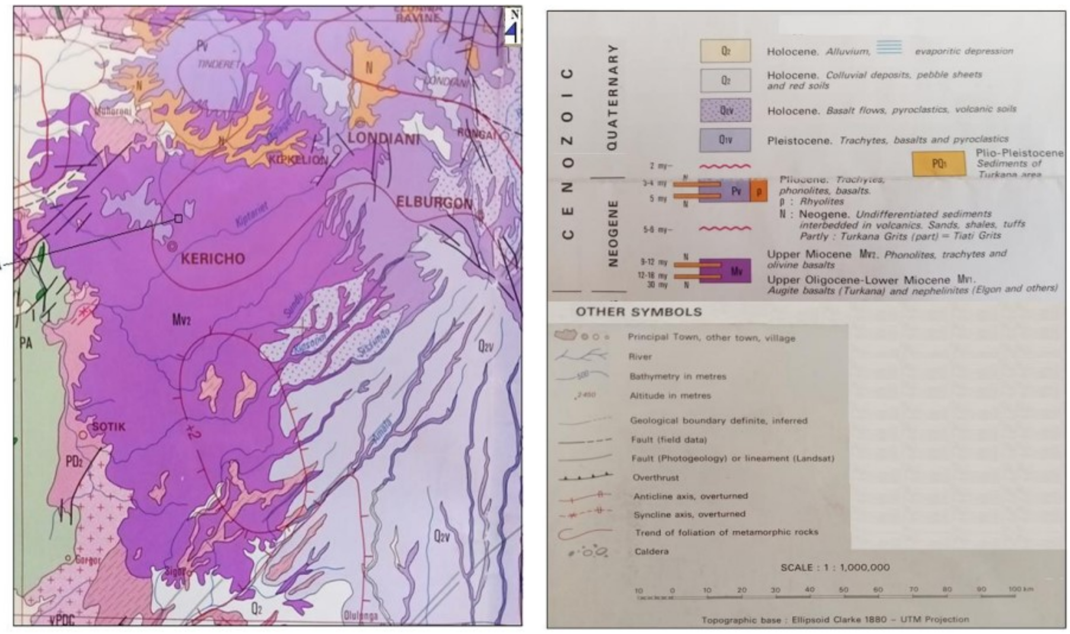


**Fig.1.2. Location of the Ainamoi Area and Major Rock Cover**

The study area is located on volcanics of phonolitic composition belonging to Kapcheptoror Hill, which measures 7183 feet (2155 meters) in height. The area covered is approximately 4 sq km and has a population of approximately 5,000 people.

Physiographic and Natural Conditions: The topography of the region is undulating (Fig. 1.2). Since the land's overall slope faces westward toward Kisumu Port on Lake Victoria, drainage flows in that direction. The region creates a hilly shelf that separates Kisumu County's lowlands from the Mau Escarpment. The Tinderet Hills surround the region to the north and the Mau Escarpment to the northeast. In between are areas of gently rolling land with sporadic small hills inside farming areas. The hilly Kipkelion regions, which roll and trend towards the Fort Ternan-Koru lowlands, are located far to the northwest. The county's middle section rises eastward toward the 3,000-meter-high Mau Ridge.

Slightly sloping from 2,500 meters to roughly 1,800 meters above sea level, the Kericho plateau makes up the county's center. There are several rivers in the region, including the Ainamoi, Kipchorian, Koror, and Sosiot rivers. The area has good drainage.

Some of these rivers have waterfalls and rapids that could be used to generate hydroelectric power. They also have local tourist attractions and adventure sites, like the waterfall on the sloping ridge that is home to the Bagao caves and the archaeological sites (where hominid fossils of Homo sapiens are found) across from the Fort Ternan Trading Center (Rop, Namwiba and Mwanganga, 2020).

Climatic and Ecological Conditions: Kericho County, being emplaced in a high altitude region, continues to receive suitable precipitation for maintenance of tea production on commercial scale, as the main agricultural engagement for the farm owners. The area receives relief rainfall, with moderate temperatures of 17oC, and has a low evaporation rate. The temperature ranges downwards from 29oC to as low as 10oC during the rainy season. The highest rainfall received averages at about 2125mm. The lower parts of the county (i.e. Soin and parts of Kipkelion) receive the least amount of rainfall of 1400mm per year. The area experiences two rainy seasons: the long rainy season which occurs between April and June, and the short rainy season which occurs between October and December every year. The driest season is mostly from January to February. Variations in temperatures and rainfall for the Ainamoi Area and neighboring places are mainly determined by variations in the altitude of the entire county. The Study Area is situated within the drainage region of the Lake Victoria Basin Authority, despite its hilly topography. The hilly terrain in certain areas of the region facilitates soil erosion. However, this problem is mitigated by the presence of a dense vegetation cover and rock barriers that are erected on farms to arrest the surface runoff.

**Infrastructure**

Roads Infrastructure: The area has a road network with a bitumen surface that connects Kericho town to the Ainamoi Center while heading towards Muhoroni, Koru, and Fort Tenan areas. Figure 1.3 shows typical bituminous surface roads that traverse the area where rich bauxite deposits occur (Ainamoi, Kapmelilo, and Koisirat villages).


**Fig. 1.3. Typical Flexible Pavements of Bituminous Surfacing Traversing the Study Area of the Rich Bauxite Deposits**

The study area is also served by gravel roads, particularly through the Poiywek, Kapsoit, and Ainamoi centers. Some non-gravel roads are also present, but they are earmarked for upgrading to receive bituminous surfaces. One of the gavel roads, where the car is, was constructed using lateritic material extracted from the surrounding area. As shown in Figure 1.4, the material had been stored for future transportation to cement manufacturing companies in Kenya and Uganda.


**Fig. 1.4. Typical Bauxite Lateritic Gravel Material (GM) from Study Area**

**Geological Setting:** The Geological setting of Kericho is generally characterized by Kericho Cenozoic plateau phonolites and trachytes of Tertiary to Recent Age (Binge, 1962). The Study Area is predominantly covered by Tertiary lavas (phonolites) and intermediate igneous rocks which are underlain by metamorphic facies of the Mozambique Belt at considerable depth (Rop and Namwiba, 2018). The volcanic rocks (phonolites/trachytes/tuffs) form an extension of volcanic eruptions, which constitute the Mau Escarpment. The typical exposures are illustrated in Figure 1.5. The volcanic rocks were a source of residual bauxite accumulation in the Kiburet area and lateritic deposits of marram quality (Fig.1.4). Trachytic dykes can also be encountered in the area. (Fig.1.6).


**Fig.1.5. Slope cut showing exposure of Phonolitic Lavas**


**Fig.1.6. Slope cut showing exposure of trachytic dyke (D)**

Before down-warping of the Gregory Rift Valley to the eastern part of Figure 1.2, the eruptions occurred. Additionally, the eruptions were associated with mixtures of volcanic ash and other prolific rocks (pyroclastics) The main soil cover is represented by a complex mixture of red volcanic, igneous, and metamorphic soil masses, forming the Quaternary Holocene alluvium/colluvial deposits (Rop, Namwiba and Maina, 2018). It was found that the complex soil mixture had an average pH of 5.6, indicating that the soil was relatively acidic. The drainage system of the Kericho Area witnessed incision processes during rejuvenation episodes, which resulted in volcanic phonolites forming interfluves accompanied by a general tilting of the physiography to the SW direction. However, the direction of flow for phonolites is still evident by the orientation of flow-vesicles and phenocrysts, which form a southwesterly alignment. The survey consisted of detailed geological and geochemical mapping and an approximate estimation of the tonnage of the bauxite minerals deposit. The study identified the areas that are economically viable for the extraction of the bauxite mineral, based on the findings of geochemical analyses, backed by the geological characterization of the rocks that comprised the visited areas.

# MATERIALS AND METHODS

The mining industry in Kenya has been primarily focused on the production of non-metallic minerals, such as soda ash (trona), fluorspar, diatomite, natural CO2, kaolin, gemstones, and limestones deposits for production of cement and agricultural lime Other deposits include iron ore mining, though this is only on a relatively small scale in Kitui, Meru, Taita Taveta and Kilifi counties. Base Titanium, a leading base metal mining company in Kenya, is currently extracting titanium from placer deposits in Kwale. In western Kenya, gold is also being mined by artisanal miners and small-scale companies, such as Acacia Mining Company. Since the 1950s, when there was a gold rush in Kakamega and Migori, gold mining has been abandoned for over 50 years. However, mining currently accounts for less than 1% of Kenya's annual gross domestic product (GDP).

Bauxite Occurrence and Mining in Kenya: Bauxite is an ore of aluminum that has not been fully explored in the country. For instance, in Kericho County, bauxite deposits hold significant economic significance in the Ainamoi region. Recently, large-scale bauxite extraction has been conducted in the Poiywek mines in the Ainamoi Sub-County. Small-scale bauxite mining is also being undertaken from small-located deposits that have not yet been fully developed or explored. The quarried materials are mainly sold to the cement industry, where they are used as additives in the manufacture of cement. A typical cement manufacturing company that is capable of utilizing the additive raw material is the East African Portland Company, situated in Athi River. Some weathered geomaterial ballasts for construction purposes (Rop and Namwiba, 2020) are being quarried from the Lalliat sub-location and ferried to Kericho Town.

In the past, local smelting of iron ores was powered by charcoal in rural areas to produce sponge iron. The iron produced was used to produce basic tools and weapons for cutting and hunting. However, the practice was replaced by increased trade with industrialized countries, which involved the supply of readymade tools and machines at comparatively low prices.

**Bauxite Occurrence in the Project Area:** Bauxite occurs in aluminum-rich rocks of the project area as $Al_2O_3$ and segregation has been derived from nephelinitic lavas of phonolites. Earlier scholars who have documented evidence of Bauxite include Rop (2014), who described the presence of thin layers of Bauxite cover in Kericho County, as cited by Keter and Koech (2018). Indeed, the extraction of the deposit is evident on a limited scale in a few shallow un-mechanized excavation pits, in contrast to the large-scale bauxite mining operations in Ghana, which are owned and operated by Ghana Bauxite Company Limited, as shown in Figure 1.7. The Ghanaian mine conducts open pit operations. The mining operations face minimal difficulty due to the low stripping ratio. The typical proportion of $Al_2O_3$ content in crude bauxite ore extracted from the mine is approximately 49%; however, it can be elevated above 50% if the Bayer process of leaching is employed. That concentration bears a striking resemblance to that of the Poiywek Ainamoi Bauxite Deposits, with an average concentration of 37.5%. However, it can be enhanced through the application of leaching techniques.

**Bauxite Formation:** Bauxite deposits are formed chiefly by the physical, chemical and biological weathering of aluminous-rich source rock, often lava flows. Almost all bauxite deposits are in situ occurrences. However, other deposits were transported to their present locations through the leaching of seeping fluids. Bauxite deposits are found in rocks ranging in age from Precambrian to Holocene (Rop and Namwiba, 2019). Most deposits of this type are found in the tropics and a few occur in the temperate belts, but the climate was likely tropical or subtropical at the time of their formation. Nearly all bauxite ores belong to the Cenozoic Age.

(Source: Company website)

**Fig.1.7. Bauxite Mining and Processing by Ghana Bauxite Company Limited**

**Formation Process:** The processes that lead to the formation of bauxite are more intricate than first thought. The following examples of feldspar chemical weathering offer insight into the general net formation sequence for bauxite mineralization:

Step 1: Acidification of rainwater $CO_2 + H_2O \rightarrow H_2CO_3$ $H_2CO_3 \rightarrow HCO_3^- + H^+$+ $HCO_3^- \rightarrow 2CO_3^{2-} + 3H^+$

Step 2: Carbonic and humic acids (from soil) react with feldspar, leaching potassium and silica, and hydrating the alumino-silicate structure to form an illite clay:

$3KAlSi_3O_8 + 2H^+ + 12H_2O \rightarrow KAl_3Si_3O_{10}(OH)_2 + 2K^+ + 6Si(OH)_4$

Step 3: Further leaching removes the remaining potassium, transforming illite to kaolinite: $2\ KAl_3Si_3O_{10}$

$(OH)_2 + 2H^+ + 3H_2O \rightarrow 3Al_2Si_2O_5(OH)_4 + 2K^+$

Step 4: Kaolinite is then decomposed to form insoluble gibbsite that contains the expected alumina component and soluble hydrated silica as follows:

$Al_2Si_2O_5(OH)_4 + 5H_2O \rightarrow 2Al(OH)_3 + 2Si(OH)_4$

Kaolinite Gibbsite Hydrated silica

A mixture of remnant minerals is called 'laterite' and is a common surface feature in tropical areas. If it has a sufficient concentration of alumina, but low silica content, then it is characterized as 'bauxite. Many of the world's major deposits of bauxite are found in lateral bauxites.

**Bauxite Chemical Composition:** Although bauxite comprises a variety of minerals, the composition for elemental analysis typically identifies other metal oxides. The analysis is usually performed using the method of X-Ray Fluorescence Spectrometry (XRF). Other classical methods are also available, depending on the economics involved.

**Residual accumulation of Bauxite:** Bauxite is found in laterite deposits at or near the ground surface of elevated terrains of warm humid environmental conditions. It typically manifests as pisolitic gravel or as a hard outcropping surface layer. The typical exposures encountered within the study area are shown in Figure 1.8.


**Fig.1.8. Slope cuts of exposed, intact in (a) and loose friable in (b) with inset screened bauxite material in (b)**

Gravel residual deposits can also be bauxitic, depending on how much aluminum the deposit contains. Residual accumulations are frequently observed at a depth ranging from 0.15 meters to 5 metres. Bauxite ore ranges in character from solid hard cap mass to friable fragmental deposits or nodular material, to unconsolidated finely nodular pisilotic gravel (Fig.1.9). Figure 1.9 (b) also depicts kaolinitic encrustations in a pale grey coloration on the unweathered rock exposures at the foot of the slope cut.

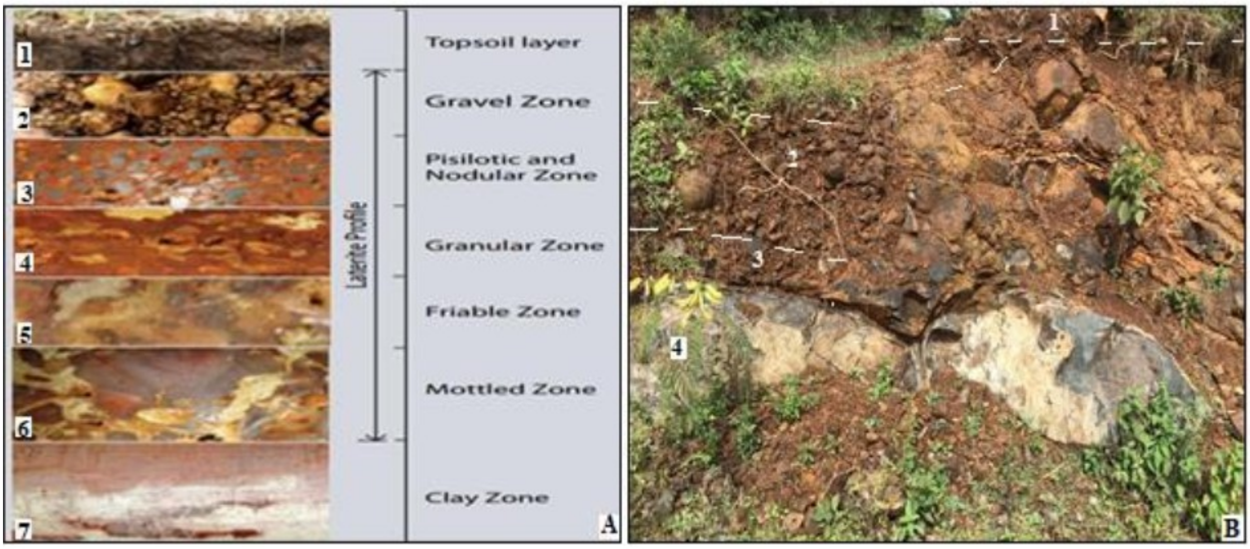


**Fig. 1.9. Schematic show for bauxite profile (A) and typical field exposure in the Area (B)**

Bauxite gravel is usually composed of rounded, light brown to red brown nodules. Some gravels are darker brown to black. These gravels are predominantly composed of iron rather than aluminum, and it is possible that they may not contain sufficient aluminum to be utilized as ore. When exploratory drilling is carried out, different profiles are delineated. The profiles indicate various types of soil and overburden, gravel, bauxite, and clay encrustations in three dimensions. The analysis of samples is conducted to ascertain the quantity of aluminum oxide present. When mining operations are due, planning is based entirely on the presence and distribution of economic grade aluminum oxide. The mining process involves the removal of topsoil and the storage of soil adjacent to the disturbed areas for subsequent rehabilitation requirements. When actual bauxite is mined, extraction targets areas that are rich in the ore. Typically, multiple mines are exploited simultaneously in order to furnish the refinery with a consistent grade of ore. Overburden, gravel, and waste materials are not processed, but they can be used to construct and maintain haul roads, bunds, and infrastructure pads. They can also be sold locally for use as an additive in cement production.

**The mining process are outlined as;**

Clearing of vegetation removal of top soil and setting aside the soil for rehabilitation measures in accordance to a pre-scheduled and approved plan (Fig. 1.10), Removal of the remaining overburden by using Scrapers and excavators to expose the cap rock or apply blasting process where applicable, Mining of the enriched bauxite using excavators, filling of the material onto haul trucks using loaders and then transporting the material to a crusher for comminution process. Backfilling of mined out areas with the reserved top soil material that had been removed, followed by re-vegetation practice using indigenous plants of the area.

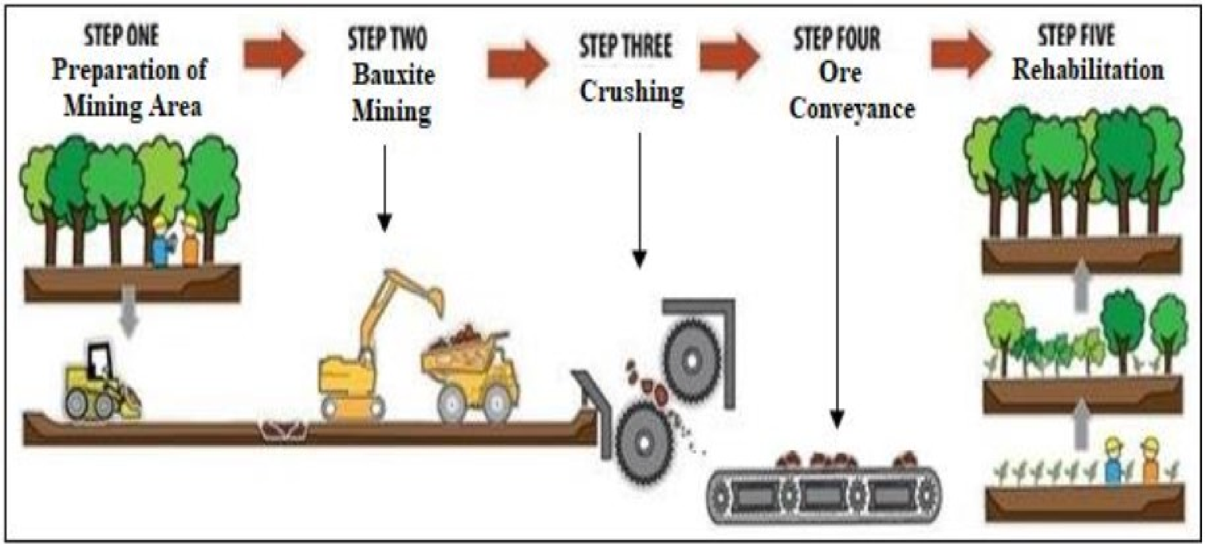


**Fig 1.10. Schematic of a Typical Mining Process for Lateritic Bauxite**

Typical Mineral Processing of Bauxite Ore Comminution: Crushing and grinding processes are used to break down the ore to a smaller size suitable for transportation or beneficiation.

**Beneficiation:** The beneficiation of lateritic materials may include dry screening to remove fine particles with higher silica content, or simple washing to remove adherent clay minerals. In countries such as Brazil, more sophisticated beneficiation techniques have been used, such as dense media separation and spirals. At least one refinery in China uses froth flotation for silica removal. Nevertheless, the majority of bauxites deemed economically viable necessitate a minimal or non-existent beneficiation process (Kasomo, *et al*., 2018).

Transport: Bauxite can be transported by any available means, depending on affordability. The methods include the use of off-road trucks, rail, conveyor systems, ships, and even piped slurries ready for mineral extraction.

## GEOCHEMICAL INVESTIGATIONS AND DISCUSSION

**Desktop Study:** Previous reports, other relevant information, and work done in the area of interest were captured to gain insight into bauxite mineralization. During the preliminary stage of the desktop study, other areas with similar geological conditions were also addressed for comparison.

**Geological Reconnaissance Survey:** Reconnaissance is the preliminary examination of the general geological features and characteristics of a specific site of natural resources or intended construction (Fig. 1.11). Reconnaissance was conducted in order to familiarize the land owners with the area and inform them of the intended activities that were to be undertaken during the period. The one-day visit enabled the identification of specific locations of interest based on the established perceptions gathered from the preliminary stage desktop study.

The reconnaissance study conducted within the Ainamoi regions involved visiting bauxite deposits areas within individual farmers, conducting pitting, preliminary identification of rock units, and collecting samples for laboratory assay geochemical analysis. It also involved gathering general information and photographing bauxite rock exposures/outcrops, and identifying areas with geological structures such as faults, folds, foliations, and unconformities that were likely to affect reconnaissance surveys and future mining processes. A brief study of the general infrastructure was conducted to assist in the selection of sites for future proposed investigations. Further efforts were also made to reach a consensus with land owners regarding the inclusion of field guides from the region. Furthermore, land owners are usually involved when prospectors seek mining consents within a particular mineral prospecting area.


**Fig. 1.11. Slope cuts sampled for Mineral Evaluation, Ainamoi Area**

Indeed, any investor who is interested in reaping the benefits of scattered bauxite deposits in those farms must personally obtain signed consents from the concerned farmers. After desktop and field reconnaissance studies have been carried out, subsequent detailed geological work follows to identify anomalous areas (rich with bauxite deposits) after detailed geochemical sampling investigations have been completed. This procedure is fundamental and must be implemented before the mobilization of mining equipment and manpower to address the actual activities of open-cast mining (Rop, *et al*., 2020 and 2021).

**Detailed Survey:** Based on the preliminary findings obtained during the reconnaissance site visit, a comprehensive survey was conducted in localities that had been identified as promising. The localities were gridded and a systematic sampling procedure was devised for the subsequent analyses (Fig.1.12). The drilling of holes located on rocky positions was omitted. During meticulous fieldwork, samples were collected and data was recorded for the pits and auger holes excavated. GPS equipment was used to obtain the coordinates and compass directions for each locality, as well as the elevation. The depth of each excavation was measured using a tape measure, and images were captured using either Android cell phones or iPads in accordance with the measurements.

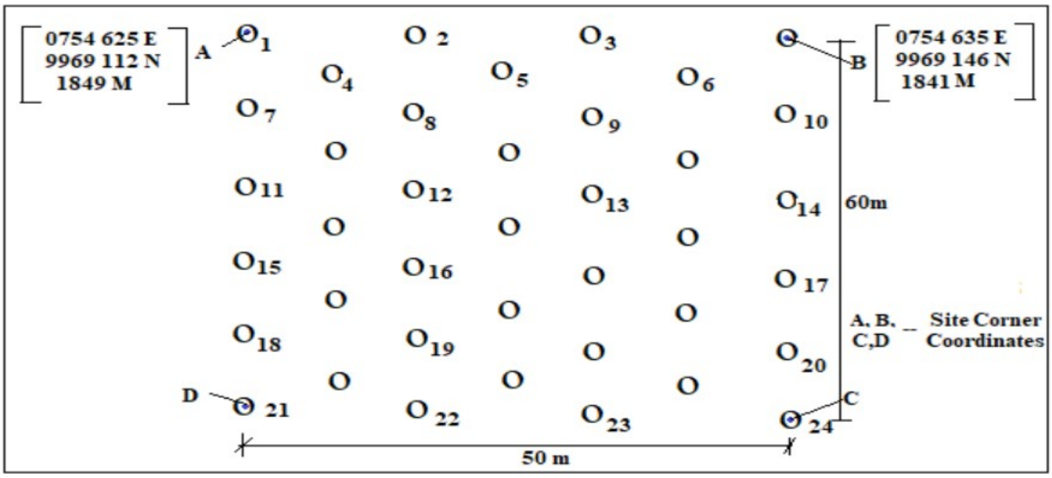


**Fig. 1.12. Typical Gridded Layout for Sampling Sites (Land Owner-Florence Rono)**

**Hand Auger drilling:** Landowners for the Area were contacted in advance in order to schedule drilling sessions. The drilling procedure was executed by employing a hand auger (Fig.1.13) In most cases, the rig drilled holes were extended to a maximum depth of one meter. Each drill hole was immediately plugged with a conical plastic bag to a minimum depth of 30 cm, from which two samples were collected and labeled as 'Sample A1' and 'Sample A2'. The sample 'A2' underwent screening/sieving using a 3mm screen, was weighed, and the weight obtained was recorded. Nonetheless, sample A1 was not subjected to screening but was solely weighed and the weight obtained was recorded. Labeling of the samples included the name of the land owner as appropriate. The drilled hole and pits were subsequently refilled with the soil material (spoil) that had been removed. The depth of the organic top soil was recorded by keenly observing the changes in the drill spoil after every 15 cm depth. Upon reaching the bauxite layer, the depth was promptly recorded, and the overburden spoil was removed to facilitate the accumulation of bauxite samples during the manual excavation. In some areas, the overburden was removed manually with a hoe, before actual excavation proceeded to the anticipated suitable depth. The holes were drilled at a distance of 15 meters by 15 meters. However, when a hard rock exposure was encountered, one pit or drill hole was found at the mid-point by joining the diagonals.

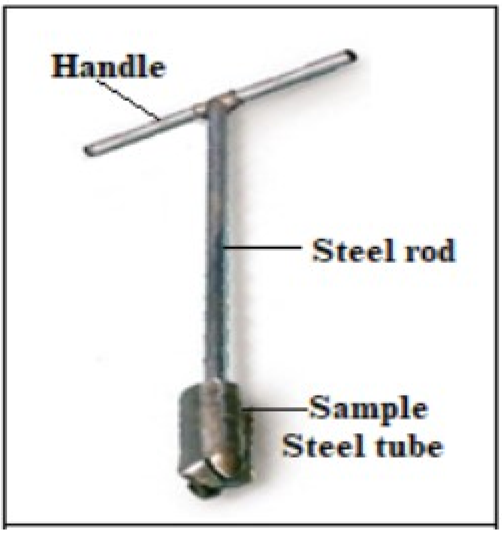


**Fig. 1.13. Typical Hand Auger**

**Pitting Activities:** Human labor was also employed in localities, where pits measuring 0.92 meters in diameter were excavated. The depth of the digging varied depending on the degree of weathering. In order to obtain a clear exposure for the bauxite layer, including variation between adjacent pits, an adequate depth was ensured for each pit. The observation, description, and weighing of the material collected were executed as had been done for the hand auguring.

**Acreage Determination:** The acreage of land parcels was determined after the individual land owner's details were recorded. It was accomplished by using an Android handset with a GPS facility to record coordinates with reference to Google Maps. Zooming was performed in order to obtain property location and then calculate the acreage using the algorithm in-built into the device. Localities with rock outcrops that were likely to have less bauxite mineral deposits were also marked.

**Analytical Methods:** Modern geotechnical methods are currently in use for the analysis of rock or soil samples. The X-ray diffraction method was found to be convenient and selected for the analysis of samples collected from the Study area. A total of 358 samples were analyzed and the results were obtained.

The results were obtained from X-Ray Fluorescent Analysis (XRF). The averaged outcomes obtained from X-ray Fluorescence are as follows:

**Table 1.1. Averaged results for whole rock XRF Analysis**

| Land Owner | Concentration (%) | | | Approx. Deposit Thickness (m) | Land Parcel Acreage (Hectares) |
|---|---|---|---|---|---|
| | $Al_2O_3$ | $SiO_2$ | $Fe_2O_3$ | | |
| Alice Rono | 38.345 | 43.696 | 14.672 | 0.915 | 0.405 |
| Andrew Rono | 35.715 | 48.015 | 12.938 | 0.610 | 0.284 |
| Antony Marusoi | 36.483 | 43.809 | 16.067 | 0.915 | 0.527 |
| Bernard Langat | 35.271 | 47.620 | 13.532 | 0.915 | 0.243 |
| Cecelia Tergech | 38.969 | 44.587 | 13.230 | 1.220 | 0.203 |
| Daniel Mutai | 39.945 | 42.468 | 14.869 | 0.610 | 0.405 |
| Daniel Tonui | 38.726 | 45.945 | 12.220 | | |
| Ernest langat | 35.747 | 47.161 | 13.430 | 0.915 | 0.243 |
| Florence Rono | 38.152 | 44.677 | 13.201 | 0.610 | 0.527 |
| Paul K | 34.998 | 47.315 | 14.082 | 0.915 | 0.162 |
| Phillip Koech | 37.221 | 46.765 | 12.712 | 0.610 | 0.608 |
| Richard Tonui | 40.746 | 40.906 | 15.413 | 0.610 | 0.608 |
| Tergech Samwel | 37.628 | 43.529 | 15.632 | 0.915 | 0.405 |
| William Ruto | 36.959 | 46.293 | 13.233 | 0.610 | 0.527 |
| Overall averages | 37.493 | 45.199 | 13.945 | 0.798 | ------------ |
| | | | | | Total = 5.144 |

**Bauxite Minerals:** It is clear from petrology and mineralogy that the project area is rich in bauxite deposits ($Al_2O_3$) and is also rich in iron ore ($Fe_2O_3$) The variation in the composition of the nephelinitic phonolytic lava can be attributed to the presence of a significant amount of iron oxide constituent, which varies from location to location. Lava is the source rock for both constituents and they overly metamorphic rocks beneath.

**Estimated Economic tonnage of bauxite in Ainamoi Area:** The preliminary estimation. The deposit for the sample is estimated as follows. From Table 1.1: Total land area = 5.144 ha. Average depth = 0.79m

Thus, Total Tonnage = Surface area * thickness
= (5.144*10000*0.79*0.353) tonnes
= 14, 345 tonnes

The current estimated price on the Kenyan market for calcined bauxite is $120 - $ 300 per tonne, indicating an average of $ 210 per tonne. The calcination process results in the drying of the raw material and the enhancement of the alumina content, while simultaneously decreasing the content of iron ore.

**Iron ore mineral**

**Estimated tonnage of Iron ore:** According to Table 1.1's geochemical results, iron ore may make up 45% of the Study Area's deposit. Thus, the amount of iron oxide in the raw bauxite could be at least 6,455 tonnes out of the preliminary estimated total tonnage. When drilling is carried out to intercept the source rock as indicated in the recommendations, this estimate will undoubtedly increase.

# RECOMMENDATIONS AND CONCLUSION

**Comparison of results for bauxite chemical composition:** The mineralogical and subsequent chemical composition of lateritic deposits hinges entirely on the mineralogical composition of the source rock and the tropical conditions that initiated and continue to contain the ongoing leaching-based reactions. This section presents a comparison between the chemical composition of the bauxite results obtained from the Study Area and those obtained by other experts for four of the leading bauxite mining nations. The International Aluminum Institute recommends that the composition of high-quality bauxite deposits ranges between 31 and 52 percent. The institute additionally provided anticipated average thicknesses for a mineralized bauxite layer and its overburden, as depicted in Table 1.2.

**Table 1.2. Mineralized bauxite layer and its overburden**

| Bauxite properties | Minimum | Maximum |
|---|---|---|
| Average bauxite layer thickness | 2 m | 20 m |
| Average overburden thickness | 0.4 m | 12 m |
| Average available alumina content (Al2O3) | 31% | 52% |

The ceiling is based on the fact that bauxite deposits of the highest quality are presently found in Australia, and the country is also leading in mining of the natural mineral resource. Rio Tinto is a major mining company that extracts bauxite from its Weipa mine in Queensland and the Gove project in the Northern Territory of Australia. According to Geoscience Australia, Gove and Weipa are among the world's highest grade bauxite deposits, with average grades being between 49% and 53% by weight in alumina content according to Brown *et al*, 1992. Chemical compositions of bauxites deposits in Guinea, Ghana, Brazil, India, and the Ainamoi Area (Kenya) are as follows:

**Table 1.3. Major chemical constituents (Wt. %) from Fria Bauxitic Profiles, Guinea (After B. Boulangé1, G. Bouzat' and M. Pouliquen, 1996)**

| Constituent | Chemical composition for Profile C (wt. %) | | | | | Average (Wt. %) |
|---|---|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 | |
| SiO2 | 1.08 | 1.42 | 1.55 | 1.29 | 7.45 | 2.558 |
| A12O3 | 42.99 | 41.10 | 56.43 | 24.92 | 31.70 | 39.428 |
| Fe2O3 | 27.04 | 32.92 | 8.21 | 53.48 | 39.47 | 32.224 |
| TiO2 | 3.37 | 2.61 | 2.99 | 1.17 | 1.96 | 2.420 |
| MnO | 0.09 | 0.02 | 0.02 | 0.01 | 0.02 | 0.032 |
| MgO | 0.02 | 0.03 | 0.02 | 0.05 | 0.17 | 0.058 |
| CaO | 0.02 | 0.02 | 0.06 | 0.10 | 0.08 | 0.056 |
| Na2O | 0.06 | 0.04 | 0.08 | 0.02 | 0.12 | 0.064 |
| K2O | 0.01 | 0.02 | 0.02 | 0.02 | 0.12 | 0.038 |
| H2O+ | 23.70 | 21.80 | 28.15 | 18.02 | 17.77 | 21.888 |
| Total (%) | 98.38 | 99.98 | 97.53 | 99.08 | 98.86 | |

**Guinea**

In Guinea, bauxite deposits are found in the Fria district, in the western part of the Guinea Republic. The deposits have been exploited since the year 1960. They are lateritic bauxites, located on the upper parts of plateaus, having evolved from the weathering of Paleozoic Schists. The deposits were formed on the Paleozoic cover of the West African Craton, which was uplifted during Tertiary times with a distinctive consistency within the lateritization profiles. In most localities, the profiles have thicknesses of 25-30 m. The primary mineral composition of the ore is represented by gibbsite associated with pyrophyllite, Alsubstituted gœthite, and kaolinite. The geochemical results for lateritic rock samples obtained from the Fria deposits are shown in Table 1.3.

## Ghana

In Ghana, the main bauxite deposits are found in four regions: Awaso, Kibi, Mt. Ejuamena, and Nyinahin. The Awaso deposit has remained unprocessed since 1942, primarily exported to Europe. However, as of September 2021, Ghana Integrated Aluminium Development Corporation (GIADEC) had selected a competent company to construct a refinery facility in order to address the dire situation. The company, Rocksure International, intends to develop the estimated 390 million metric tonnes of bauxite deposit situated at Nyinahin-Mpasaaso in the Ashanti Region of central Ghana. The company intends to construct a refinery plant at an estimated cost of \$1.2bn. The plant is expected to extract a projected five million tonnes of bauxite annually, transform the raw bauxite into aluminum products, and in the process generate over 1,000 jobs (NS Energy, 2021) Table 1.4 shows the chemical composition of bauxite from the Kibi deposit.

**Table 1.4. Chemical composition (wt. %) of bauxite samples from four pits of Kibi deposit in Ghana (After E. E. Amissah, S. K. Y. Gawu and J. S. Kuma., 2012)**

| Constituent | Chemical Composition by Wt. (%) | | | | Average (Wt. %) |
|---|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | Sample 4 | |
| SiO2 | 4.5 | 1.0 | 5.2 | 1.8 | 2.5 |
| TiO2 | 3.7 | 4.1 | 2.8 | 4.0 | 3.3 |
| Al2O3 | 45.6 | 56.5 | 46.0 | 53. 7 | 46.6 |
| Fe2O3 | 22.1 | 8.4 | 18.3 | 13.8 | 22.5 |
| CaO | 0.05 | 0.05 | 0.05 | 0.05 | 0.03 |
| MgO | 0.06 | 0.02 | 0.05 | 0.04 | 0.02 |
| MnO | 0.02 | 0.12 | 0.03 | 0.01 | 0.03 |
| V2O5 | 0.15 | 0.11 | 0.11 | 0.13 | 0.12 |
| P2O5 | 0.19 | 0.01 | 0.14 | 0.15 | 0.17 |
| LOI | 22.1 | 27.5 | 27.2 | 24.2 | 24.6 |
| Total (%) | 98.47 | 97.81 | 99.88 | 44.18 | |

## Brazil

The Santa Catarina bauxite deposit is used for the manufacture of refractory products. Bauxite mined from Brazil is widely used for refractory production due to its high alumina content, which has a high melting point compared to other constituents. The largest reservoir for refractory bauxite in Santa Catarina State is Santa Catarina State. The utilization of contemporary technologies in the characterization of bauxite deposits continues. The technologies employed to characterize bauxite from Santa Catarina ware include chemical (X-ray fluorescence), thermal (differential thermal analysis), mineralogical (X-ray diffraction), and microscopic (optical microscopy and scanning electron microscopy). As a result, bauxite was found to be suitable for use as a refractory material provided that its alumina content (Al2O3) was above 45% and its concentration of iron oxide was below 6% (Bernardin *et al*. 2012). Excess iron oxide (Fe2O3) and other oxides can be reduced by subjecting the raw bauxite to leaching using hydrochloric acid (Jenkins and Sinha 1995; Zafar 2008). Typically, Iron oxide exhibits a low melting point and is susceptible to deformation during furnace liming. Therefore, it is recommended to reduce its initial content in raw bauxite. Bernardin *et al*. (2012) employed X-ray diffraction techniques to ascertain chemical constituents in diverse bauxite samples. Table 1.5 shows the average results obtained for natural and leached bauxite samples. Para-Brazil is also endowed with bauxite with a high alumina content. Investigations were undertaken to determine; If the grinding stage in the leaching process (Bayer process) has resulted in any bulk structural modification of bauxite, To determine the analytical method for quantifying reactive silica with available alumina content (Carnero *et al*, 2009).

The techniques employed to characterize the ground test samples included Infrared spectra (IR), X-ray diffraction (XRD), X-ray fluorescence (XRF), and scanning electron microscopy (SEM). The grinding process used resulted in no major bauxite bulk structure modification. Furthermore, a suitable analytical method was developed to measure reactive silica and available alumina contents. According to Carnero *et al*., 2009, the chemical composition of the bauxite material that was investigated from both Santa Catarina and Para - Brazil is also shown in Table 1.5 together with the characterization results for Santa Catarina.

## India

In India, bauxite deposits occur mainly as derivatives from basaltic lava, especially in the hazaridadar plateau of Madhya Pradesh region. Various researchers studied laterite profiles in order to determine the distribution of alumina and iron, among other constituents. Three main zones were identified, namely lithomarge, laterite, and bauxite, in ascending order. The formation of the profile involves gradual chemical weathering, which involves desilication and hydration (Sastrl and Sastry, 1982). The typical chemical composition of bauxite for the profiles is illustrated in Table 1.5 (a). Residual Bauxite deposits, akin to those found in the Pradesh region, are found in the State of Orissa, situated in the eastern region of India. The deposit is extensive and was discovered to be of metallurgical grade, located at the summit of Gandhamardan hill. The deposit that results from chemical leaching and in situ transformation of aluminous-rich rocks known as khondalite is distinct from that of Pradesh plateau basalts.

It covers a large area of 9.8 km in length and 0.75 km in average width. Bauxite occurs as a continuous, homogenous, flat-lying layer, which averages 16.6 meters in thickness. The deposit underwent extensive exploration by national corporations in stages over a 6-year period in the late 1970's and early 1980's. The exploratory work included line cutting, topographic surveying, geological mapping, pitting, drilling, sampling, mineral studies, and metallurgical tests. The typical Chemical composition of the Orissa Bauxite is as shown in Table 1.5(b).

**Table 1.5(a). Average Chemical composition of bauxite Santa Catarina and Para ,-Brazil, Brazil (After Bernardin *et al*, 2012 and Carnero *et al*, 2009)**

| Constituents | Chemical Composition by Wt. (%) | | |
|---|---|---|---|
| | Santa Catarina | | Para ,-Brazil |
| | Un-leached bauxite | Leached bauxite | |
| SiO2 | 3.5 | 5.5 | 0.77 |
| TiO2 | 0.9 | 0.6 | 1.5 |
| Al2O3 | 55.4 | 62.7 | 54.1 |
| Fe2O3 | 5.8 | 0.6 | 11.3 |
| MnO | - | - | 0.26 |
| ZnO | - | - | 0.013 |
| V2O5 | - | - | 0.038 |
| P2O5 | 0.1 | – | 0.15 |
| Nb2O5 | – | 0.1 | - |
| ZrO2 | 0.2 | 0.1 | - |
| SO3 | 0.1 | – | - |
| LOI* | 30.4 | 40.5 | |
| Total | 96.4 | 110.1 | 68.131a |
| Available Al2O3 | - | - | 52.2b |
| Reactive SiO2 | - | - | 0.4c |
| * -- Loss on Ignitionx - LOI not captured a, b, c -- for new extraction method sort for | | | |

**Table 1.5 (b): Chemical composition by Wt. (%) (After Balaton Power Inc. (2007)**

| Constituent | SiO2 | Al2O3 | Fe2O3 + TiO2 | MnO2 + CrO2 | V2O5 | P2O5 | LOI | CaO, Na2O +K2O | Total (%) |
|---|---|---|---|---|---|---|---|---|---|
| Chemical Composition Wt. (%) | 2.4 | 46.6 | 25.6 | 0.35 | 0.13 | 0.19 | 24.1 | 0.55 | 99.92 |

**Ainamoi – Kenya:** The bauxite deposits from the study area were derived from Tertiary phonolitic lavas, which are nephenilitic in composition, hence silica is undersaturated. The results of a geochemical analysis that was conducted on soil samples in February 2022 were analyzed. Table 1.1 contains the average results.

# DISCUSSION

Average composition of Alumina: Table 1.1 displays the average weight percentage of alumina in assay results for 358 samples taken from a 4 square kilometer study area in Ainamoi, Kenya. The International Institute (IAI) states that the acceptable range for composition of a quality Bauxite mineral deposit is between 31% and 52%. by mass. This demonstrates that the Study Area's bauxite deposit falls within the designated range. The deposit originated from lavas known as phonolite. Bauxite deposits in Guinea originated from the weathering of Paleozoic Schists, whereas in India they came from the Basaltic lavas and Khondalite rocks that were covered in the previous subsection.

Significance of Bayer process in mineral processing: By using the Bayer chemical process on raw bauxite material, the alumina content can be raised. When a high iron content needs to be lowered in order to find a suitable lower level at which bauxite can be used as a raw material for refractory products, the process becomes necessary. Table 1.5 demonstrated that the addition of hydrochloric acid to the leaching process resulted in a decrease in the concentration of iron oxide (Fe2O3) from 5.8% to 0.6% by weight and an increase in the content of alumina (Al2O3) from 55.4% to 62.7% by weight. It has been documented that high iron oxide content can deform processing furnaces because it melts at a temperature lower than the high melting point of alumina, which is used to extract aluminum metal.

Detailed investigations: The extent of sampling is contingent upon the excavation technique employed and the degree of chemical weathering that impacted the rock mass, resulting in the formation of the residual deposit. Hand auguring was used to extend augured holes to a maximum depth of 1 m, while pitting was done to an average depth of 0.5 m. However, it is believed that the degree of weathering is beyond the average depth reached by hand auguring. Additionally, several exposed slope cuts show a depth of more than 2m (e.g. Figures 1.3, 1.5, and 1.6).

Subgrade lateritic material: Lateritic material, commonly referred to as residual soils, is commonly employed in road construction. This scenario also applies to the Study Area, where the use of the material is shown in Figures 1.4 and 1.7. Therefore, subsequent to the removal of top soils, a thin excavation can be conducted to remove and reserve the material for that purpose. This can be accomplished prior to extending further into levels that possess higher levels of alumina than iron content. The laterite material has acceptable engineering properties for road works under standard conditions of practice. Indeed, the Ministry of Roads and Public Works found the material suitable for that purpose to be suitable.

Mineral processing plant and Job creation: For decades, Ghana has been mining and exporting raw bauxite minerals to the external market. Indeed, in September 2021, the government corporation GIADIC took a bold step in the right direction to address the issue mentioned in the previous section. Mineral processing activities will result in a rise in employment prospects, thereby benefitting the local community, in addition to the existing mining ventures.

Quarry rehabilitation and handling of tailings: The rehabilitation of quarry sites when quarrying activities become economically unviable is a healthy practice and an environmental requirement. Various methods can be applied, including reforestation, in order to re-engineer the ecosystems that existed before the excavations were carried out. The reforestation practice that is prevalent in most countries that engage in mining activities of base metals is illustrated in Figure 1.14 in Australia.

**Fig.1.14. Reforestation practice in a former bauxite quarry, Australia (After NS Energy. 2021)**

The handling of tailings is also challenging. For instance, the proposed bauxite refinery plant in Ghana is anticipated to produce a substantial quantity of tailings solids, estimated at approximately 5 million tons. Therefore, experts had to identify the best methods for handling the material, including a suitable site for containment, which they referred to as red mud. Later, the site was located in the Shama Ahanta East Municipal area. According to Amissah *et al*. (2012), the identified area posed the least risk of causing environmental damage.

Additionally, they identified 'Thickened Tailings Disposal Technology' as the optimal disposal technology for managing the red mud. It is anticipated that effecting those measures will have little or no impact on groundwater, and further that less land and water will be required for implementation, resulting in better environmental performance. Based on the above discussion, it is imperative to devise a rehabilitation program in order to exploit the bauxite deposit in the Study Area. It is anticipated that the program will encompass schedules for activities such as reforestation and containment measures for the tailings to be generated, in addition to other environmental concerns.

# RECOMMENDATION

Investment: It was found that the concentration of alumina, the source of aluminum, was within the acceptable range discussed in previous subsections. Therefore, the deposit is worthy of exploration by an investor. The mined material can be utilized as lateritic soil in road construction as it possesses sufficient bearing capacity during compaction, enabling flexible pavements to withstand the dynamic loads of light axle traffic. Drilling: The hand auguring and pitting that was conducted in the study area were not carried out to a significant depth as the fresh source rock was not intercepted. Therefore, it is recommended that machine drilling be conducted at deeper levels by means of a powered drilling rig in order to access fresh stratified volcanic lava. Therefore, it is imperative to account for all the material excavated, particularly for reporting assay precision.

The results will provide an improved estimate of the volume of the residual deposit in the study area. Mineral processing and refractory plants are utilized for their respective purposes. As discussed earlier, bauxite from the study area can be subjected to the Bayer process for the reduction of iron oxide content. When that is done, it will be appropriate to establish a plant for refractory products. The plant will provide a source of income for the local community, in line with the regulations for the issuance of prospecting licenses, such as Article 30, of the Kenyan Mining Act 2016. Aluminum plant: The construction of a processing plant within the vicinity of a mining enterprise presents numerous advantages. It also eliminates the cost of transporting the raw material to another location for processing and refinement. Additionally, additional employment opportunities will be realized, among other advantages. The processing plant has the potential to expand by utilizing comparable raw materials from nearby mines within its reach. Figure 1.15 depicts the present largest processing plant in Brazil, which handles substantial quantities of raw bauxite material.

**Fig. 1.15. Hydro Alunorte: the world's largest alumina refinery (After: Shutterstock/Tarcisio Schnaider)**

Feasibility Studies: Projects involving mining, construction, or other environmental concerns typically require feasibility studies. It is imperative that the Kenyan Environmental Authorities (NEMA) grant their authorization for the studies to be conducted. It is recommended that the project address the pertinent aspects and be provided to a registered consultant in order to generate a comprehensive report.

The identification of alternative settlements and compensation for land owners who will be displaced (as per the Mining Act of 2016); Mitigation measures to be applied for associated environmental issues to be considered to the satisfaction of the International Aluminum Institute and avoid disasters such as the one shown in Figure 1.16.

**Fig.1.16. Collapse of Ajka Bauxite Tailings Dam, West Hungary, 2010 (After Evans, K, 2015)**

Community Corporate Services and Investments: The investor will be encouraged to engage in community socioeconomic programs for mutual benefits. This approach will aid in the advancement of the local community by addressing issues such as gender parity and the needs of vulnerable groups. It is also possible to consider suitable investments in joint entrepreneurial and small-scale commercial projects. If realized, such investments will generate additional earnings in addition to the salaried income, which will boost the overall earnings for the workers and ultimately benefit the community and county.

Second Projects in Kericho and Nandi Counties: According to Keter and Ngeno (2018), the adjacent Nandi County is also known to possess bauxite deposits, particularly in the Kiptunu Area. Thus, it is highly recommended that a similar venture target Nandi County in order to increase business volumes with respect to raw materials and gross income. Alternatively, following the completion of the economic evaluation for the deposits in Nandi County, quarrying could commence and the material quarried could be processed in the same plant situated in Ainamoi Area in Kericho County. Indeed, the investment is poised to expand in the right direction with continued blessings from the community, counties, and the government as a whole. The alumina content of a bauxite deposit can serve as an additive in the production of cement. However, it would also require silica, limestone, iron, and gypsum. Other materials must be procured from distant and costly sources, making it difficult to assess the viability of establishing a cement factory in the study area.

# CONCLUSION

**We can draw the following conclusions:**

The concentration of alumina content, being the source of aluminum metal in the bauxite deposit of the Study Area, lies within the expected range for bauxite mineral resource quality and therefore compares well with similar deposits in other major bauxite mining countries. The study area contains an enormous bauxite deposit, which requires powered drilling in a grid pattern similar to the one used. The drilling should intercept the fresh source rock of the deposit. If that action is taken, it will allow the economic potential of the deposit to be re-evaluated for the entire area. If Bayer or other modern technologies, such as calcination, are applied, Ainamoi bauxite could be mined to sustain an aluminum processing plant. After completing evaluation assignments, the plant would expand rapidly if more quarries were opened up in neighboring counties, especially Nandi County. It may be feasible to establish a refractory factory, as the Bayer method of pre-processing or calcination can be utilized in the overall manufacturing processes of refractory products, as demonstrated in Brazil, a significant bauxite mining country. The field evidence gathered and presented in this report indicates the dependable mineralization of Bauxite deposits. Given that a similar deposit in Nandi County is unexploited, the quantity is enormous. Since the source rock for the residual deposit is shallow, an estimate of 6 million tonnes can be achieved with powered drilling. The present infrastructure of Kericho County is highly conducive to dynamic investments, owing to the proactive development policies and strategic plans implemented by the present county government, founded on sound vision and mission. This is a national opportunity that must be exploited for the sustainable development of the mining extractive industry.

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