The Implications of Geology and Structure on Iron Ore Mining at Wanjala Mine, Taita-Taveta County, Kenya

Keoko K. Peter, Bett K. Gilbert and Rop K. Bernard

Abstract: This paper explains how geological attributes and structure of rocks dictate mining techniques applicable at Wanjala Mines. Mineral and ore deposits occurrence is associated with other geological materials that influence their physical, mineralogical and geochemical properties hence defining the kind of mining technique and beneficiation method(s). Associated and/or paragenetic sequence affects the ore grades such as cut-off grade which may further affect the mineable ore reserve. The quantity of recoverable iron ore in Wanjala Mines is a function of the geology and the associated minerals whether elluvial, vein or lode, brecciated or fractured and/or massive deposit. At Wanjala Mines, the geology and mineralogy has less complex nature that may affect iron ore mining. Iron ore occurrence is in two forms elluvial and lode iron ore. The geographical distribution of iron ore and intensity of their anomalies dictate a biased mode of extraction for elluvial and a different method to exploit the reef iron ore; say mobile units and open pit mining respectively. Beneficiation also necessitated plant optimization methods on how to handle different sizes of materials.

Key words: Geology, mineralogy, geochemical, elluvial, lode, Wanjala Mine, Mining.

I. INTRODUCTION

Mining of iron ore is partly or fully influenced by one or combination of several factors among them being topography, geology and geologic structure, hydrogeological conditions as well as soil and general ground stability. The implications of the aforementioned factors to the whole mining process include choice of and equipment specifications, production rate, operating costs, stripping ratio and haul roads. Additionally, the structure of the rocks, that is dip and strike are key elements that determine the overall pit and bench geometries. The quality and the quantity of the net iron ore mined are determined by factors such as the gangue materials. Mineral occurrence of iron ore in Kenya has been identified but non-extensive research has been done to prove their commercial and geological attributes that may inform investors and/or government on the possible ways to not only mine but add value as well as technologies to mine and/or process to a final product.

II. JUSTIFICATION OF THE RESEARCH

Kenya’s Vision 2030 is and will be realized when factual data that feeds industrialization is available for decision making. EAC interest on singular investment on steel smelting plant is good gesture of possibility and rationale for futuristic economy that is stable and sufficient. Therefore, research into available and quality of raw materials and extraction mechanisms alongside technologies that will apply is the key determinant. This research adds knowledge to geological formation and attitude and how they directly affect mining and processing techniques.

This paper aims to provide a relationship between geological formation of iron ore at the mine and their implications to the types and mechanism of extracting and beneficiation of iron ore.

III. LITERATURE REVIEW

The Wanjala iron ore is a medium grade (<62% Fe) deposit that occurs in two forms which include the reefs and the elluvial deposits. The latter is as a result of collisional tectonics that included folding and uplift, shearing and brecciating. Following massive tectonic forces, iron ore veins were mechanically fragmented hence forming the abbreviated sections on lateral veins and further up-thrown iron ore gave rise to elluvial iron ore deposit. Alluvial iron ore covers areas near and/or along the main reefs and assumed the topographic surface at that time. The depths of occurrence of the two types of deposits vary from one point to the other due to the folding pattern which formed anticline and syncline. These resulted in uplift and sinking of the veins on some sections and other areas the reefs as well as the elluvial deposits are exposed to the surface. The reefs are shallow to deep-seated in areas that suffered extensional tectonics. Where iron ore vein is deep, a non-quantifiable alluvial iron ore occur.

Iron ore deposit is non-related with host rocks though there exists sharp contact between the metallic and non-metallic ore, for instance, iron ore deposit juts into massive quartzite or hornblende in other sections with deep-seated ore) occurrence with little geochemical interchanges of minerals. This is the reason why iron ore deposit mineralogy absolutely differs from that of the host rocks. Lack of defined metallic ore zoning shows that the original protolith was monomineralic in nature only changes came from new geological formation which created a break in the continuity of occurrence over the
area. Moreover, the deposits are structurally and topographically controlled, that is, for iron ore reefs, the visible brecciation, joints and fractures are as a result of brittle deformation caused by compressional and extensional tectonics. Additionally, the reefs’ general strike is NW-SE direction and dip towards 60 degrees NE. The elluvial deposit assumes the topographic nature of the area. Referring to the nature of mineralization, both the elluvial and reef ore are hard, compact and resistant to weathering. The deposit and host rocks relationship shows a magmatic-metamorphic genetic model, that is, a magmatic process that produced huge amounts iron pyrites which after eruption formed a sedimentary exhalative iron pyrite deposit on top of basaltic rocks. These were then metamorphosed under oxidizing conditions to form iron ore (magnetite) and ortho-amphibolite respectively.

IV. GEOLOGICAL CHARACTERIZATION OF IRON ORE DEPOSITS
The geology and structure that resulted from thermo-tectonic phases of Neo-Proterozoic Mozambique belt evolution have had implications on the mining operations of iron ore deposit at Wanjala Mine. The geology consists of quartzite, quartz-feldspathic gneiss, mica schists, amphibolite, hornblende gneiss, calcrete and iron-rich laterite. The minimum and maximum strike and dip range between N50°W and 30°NE to N50°W and 65°NE respectively. The iron ore reefs at any locality within the mining site assume the strike and dip of the rocks that enclose them. The distinct physical and mechanical properties of both the footwall and hanging wall and the iron ore reefs as well as the elluvial iron ore deposit result in either ease or difficulty with which the they are mined. The major implications are that the strip ratio for iron ore reefs which are thin and geologically and structurally set between large masses of footwall and hanging wall is higher than that experienced in the excavation and screening of elluvial deposit. The iron ore reefs are sometimes too thin as compared to footwall and hanging wall rock units, irregular and since they extend down the ground, economic extraction becomes difficult as shown in Figure 1 below. The rapid increase of the amount of overburden to be handled also imposes economic limits and/or constraints.

Figure 1 Reef iron ore

The elluvial deposit whose non-ore material is quartzite is easier and cheaper to mine depending on the ratio of the ore to quartzite and the depth of the top soil at a certain exaction point as illustrated in Figure 2 below.

Figure 2 Elluvial iron ore geo-distribution.

Contrary to this, mining the iron ore reefs is a challenging process simply because of the hanging wall geologic units. The widths of iron ore reef range from about thirty to hundred centimeters. In this scenario, removal of huge masses of hanging wall materials to only get low iron ore tonnage is expensive and uneconomical for mining at greater depth.

V. IMPLICATIONS TO MINING
Geological characterization affect in the following ways:
1. Production rate: the rate of production or excavation of elluvial iron ore deposit is fast and efficient simply because the topographical level of the ground is flat making it easy for earth-moving machines such as mobile crushing and screening plants to move from one mining block/ site to another. The depth at which elluvial deposit occur is shallow therefore, a crawler excavator can strip the overburden, extract crude iron ore and load to mobile screening machine or dumper truck. Daily
production rate will be high when the ratio of iron ore occurrence is bigger in proportion to quartzite (or gangue material). On the other hand, lode mining has similar difficulty if the hanging is wall is huge requiring intense development of the pit to extract the iron ore vein(s). Additionally, the width of the vein at given depth ranges from two to five metres as compared to the mass consolidated volume of waste material. This poses a challenge to the economics of mining operations. The dipping angle and direction of strike of the veins means the deeper it becomes more difficult, time consuming and costly as well as not commercially viable to continue mining using surface methods. Depending on the volume of the deposit after the 20m depth, it may be inappropriate to undergo underground mining (if positive results are achieved after doing further exploration).

2. The choice of mining machines and equipments: Iron ore deposit requires two distinct methods of handling because of its uniqueness in occurrence. Elluvial mining requires a mobile type of machinery and equipment such as mobile screening units that help remove huge bulk of material that others would have been handled at the plant, say fine dust or soil mass. Oversize material that requires crushing unit would be isolated from the standard sizes/ range as per the market to raw iron. Gangue material that forms the hanging wall is mainly quartzite and hornblende which is easy to extract compared to blended type of occurrence since it is non-magnetic.

3. Bench Setting or configuration: Bench and pit geometry forms the overall mining development. Mechanical properties of the geological units are quite good and therefore provide a stable ground for construction of benches. Due to these features they provide a suitable ground for mining and development on the working benches and faces of the pit. Surface mine design of the pit depends on the geometry of the ore body which determines working and non-working flanks and informs the stripping ratio and efficiency of mining activities, see Figure 4 below.

![Image](image1.png)

Figure 3 Excavation of a pit, development method

4. Haul roads: Haulage and haul roads are integral part of mining operations. Mining at Wanjala Mine has reached a shallow depth of barely 20metres. It therefore, does not pose a challenge in construction or development of rams and high walls. The slope of access road is necessary for trucks and machines to enable movement in and out of the pit as seen in figure 5.

![Image](image2.png)

Figure 4 a bulldozer pushing loose material and developing bench and access to rich iron vein.

![Image](image3.png)

Figure 5 Access road into the pit

In addition, the gradient and geometry of the access roads is still at stable configuration. The geo-position of the haul and access roads is dictated by the nature of ore body and the country rocks.

VI. CONCLUSION

Mine designing process requires that correct data on the geometry of the deposit such as size, shape, strike, dip, and quality or grade of the ore has to be obtained. This will provide an effective way of mining, processing, material handling and required machinery.

Constant acquisition of the information on the deposit such
as mineralization, rock types, the physical and mechanical properties and geometry are important for selection of mining method as well as general project economic evaluations.

ACKNOWLEDGEMENT

I wish to acknowledge Wanjala Mining Co. Ltd, R.K Sanghani (Mr. Kaburu), Mr. Joseph Mutwanthei (Resident geologist) and my family for their contribution, prayers and support in this research.

REFERENCES