Rock Density – A Tool for Mineral Prospection: A Case Study of Ajabanoko Iron Ore Deposit, Okene SW Nigeria.

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ABSTRACT

Density and density contrasts of rocks, apart from controlling gravity anomalies, have been recognized as an important physical property of geologic material which aids in the identification of rocks, estimation of ore abundance, and assessing rock conditions. The object of this work is to determine the density of the various rocks in the study area using laboratory Archimedes principles and delineate the iron ore zones in the deposit from the host rocks based on their density variation. The determined density values of 109 rock samples collected from various outcrops and massive ferruginous quartzite boulders across the Ajabanoko deposit were presented as equi-density contour maps and subjected to statistical analysis in order to determine the range of density values corresponding to the major rock types in the study area.

Analysis of the resulting data shows rocks density values in the range of 1.5 x 10^3 kg/m^3 to 3.0 x 10^3 kg/m$^3 \pm 0.8$ correlated with gneisses; while densities greater than 3.0 x 10^3 kg/m$^3 \pm$ 0.5 represent iron ore. The rock samples categorized under the iron ore also indicates frequency peaks at density range 3.1 x 10^3 kg/m^3 – 3.3 x 10^3 kg/m^3 and 4.2 x 10^3 kg/m^3 – 4.4 x 10^3 kg/m^3 $\pm$ 0.5 which signifies two iron ore types i.e. magnetite and hematite ore respectively. The comparison of the density map and geologic map of the area show a good correlation. Consequently, the results suggest that this procedure can be potentially useful for ore mineral prospecting.

(Keywords: density contrast, Archimedes principle, iron ore, mineral prospecting)

INTRODUCTION

In the world today, iron and steel are recognized as the keystones to any country's industrial development and a means of accelerating socio – economic development. The Ajabanoko iron ore deposit lies between latitude 7^0 37' 22" N and 7^0 39' 17" N and longitudes 6^0 15' 55" E and 6^0 17' 15" E (Figure 1). It is located about 200 km south of Abuja, the Federal Capital of Nigeria.

Density and density contrasts of rocks are the physical properties controlling gravity anomalies. It has been established that the greater the detectable difference in density, the more easily the bodies of interest can be isolated (Telford *et al.*, 1990); therefore the success of gravity mapping depends on a density contrast existing between ore and the host rocks. Emerson (1990) described density as the most useful single property of a geological material because it helps to identify rocks and minerals, estimate ore abundances and assess rock condition.

In this study, a total of 109 fresh rock samples were collected from outcrops and massive ferruginous quartzite boulders across Ajabanoko iron ore deposit in order to determine the density of the various rocks using laboratory Archimedes principles and ascertain if their contrasts would favor the use of gravity method for further exploration of the deposit. The analysis and interpretation of the determined rock densities have enables the delineation of the iron ore zones from the host rocks and helped establish based on density variation that the ferruginous quartzite (iron ore) in the area is of magnetite and hematite type.

GEOLOGY OF THE STUDY AREA.

The Ajabanoko deposit area falls within the Nigerian Precambrian Basement Complex, a suite of crystalline rocks exposed in over nearly half of the country extending west into the Dahomeyan of Benin Republic and east into

Cameroon (Figure 1). The study area is underlain by rocks belonging to the metasedimentary group of the Precambrian Basement complex situated within the Igarra – Kabba – Jakura metasedimentary region of south - western part of Nigeria (Rahaman, 1976 and Olade and Elueze, 1979).

The dominant lithologic units of Ajabanoko deposit area are gneisses of migmatite, biotite and granite (which are regionally emplaced), ferruginous quartzites, granites and pegmatite (Figure 2). The ferruginous quartzite is the source of the iron ore mineralization in the area (Olade, 1978; Fadare, 1983; Annor and Freeth, 1985). The patterns of the iron ore mineralization in the area as shown in Figure 2 have been discussed by Olade (1978) and NSRMEA (1994).

METHOD OF STUDY

A total of 109 rock samples were collected from different outcrops and massive ferruginous quartzite boulders at the deposit. Garmin geographical positioning system (GPS) was used for measuring the co-ordinate (longitude and latitude) at each rock sample location point (Figure 3).

There are no sample locations in the Northern ore zone because of problem of accessibility. Since these rock samples are of irregular shape, their density values (volume) were determined using the Archimedes principle. The instruments used for the Archimedes principle density determination include; measuring cylinder, electronic weighing balance, threads and water.

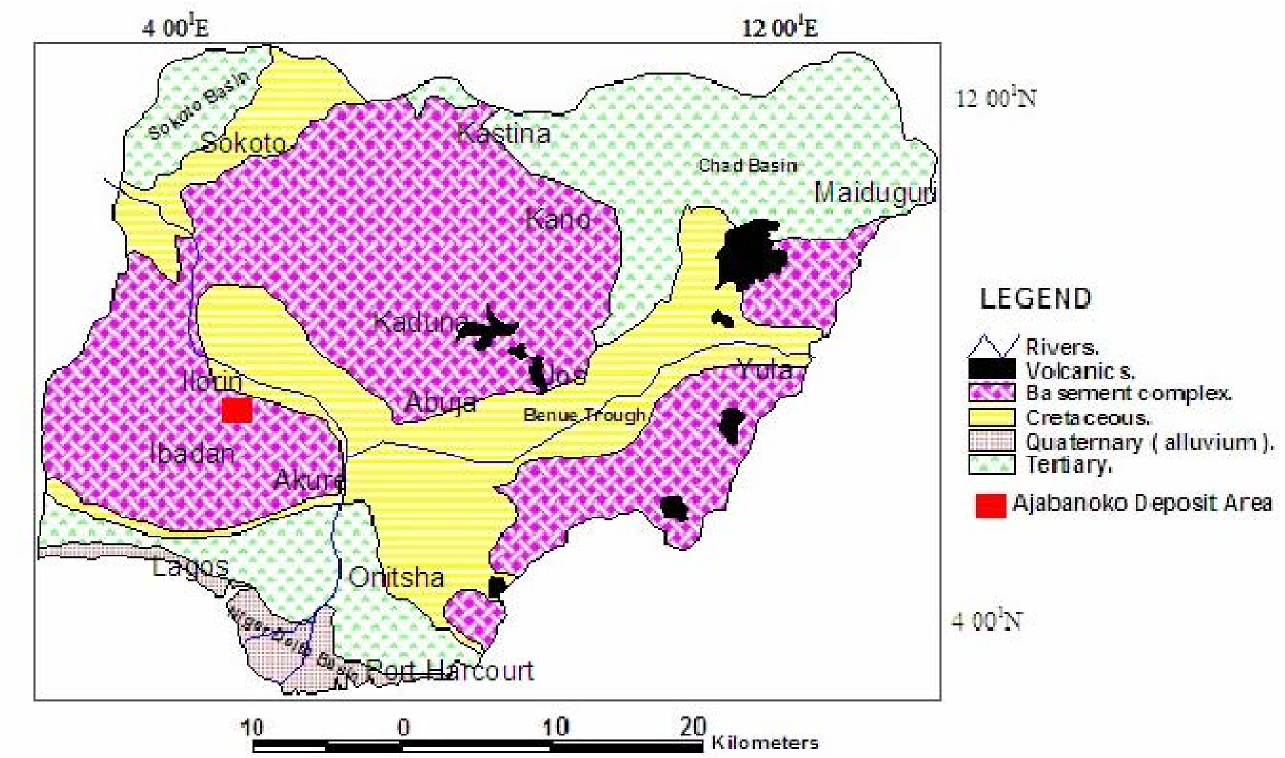

Figure 1: Geological Map of Nigeria showing the Location of the Study Area (after Odeyemi, 1997).

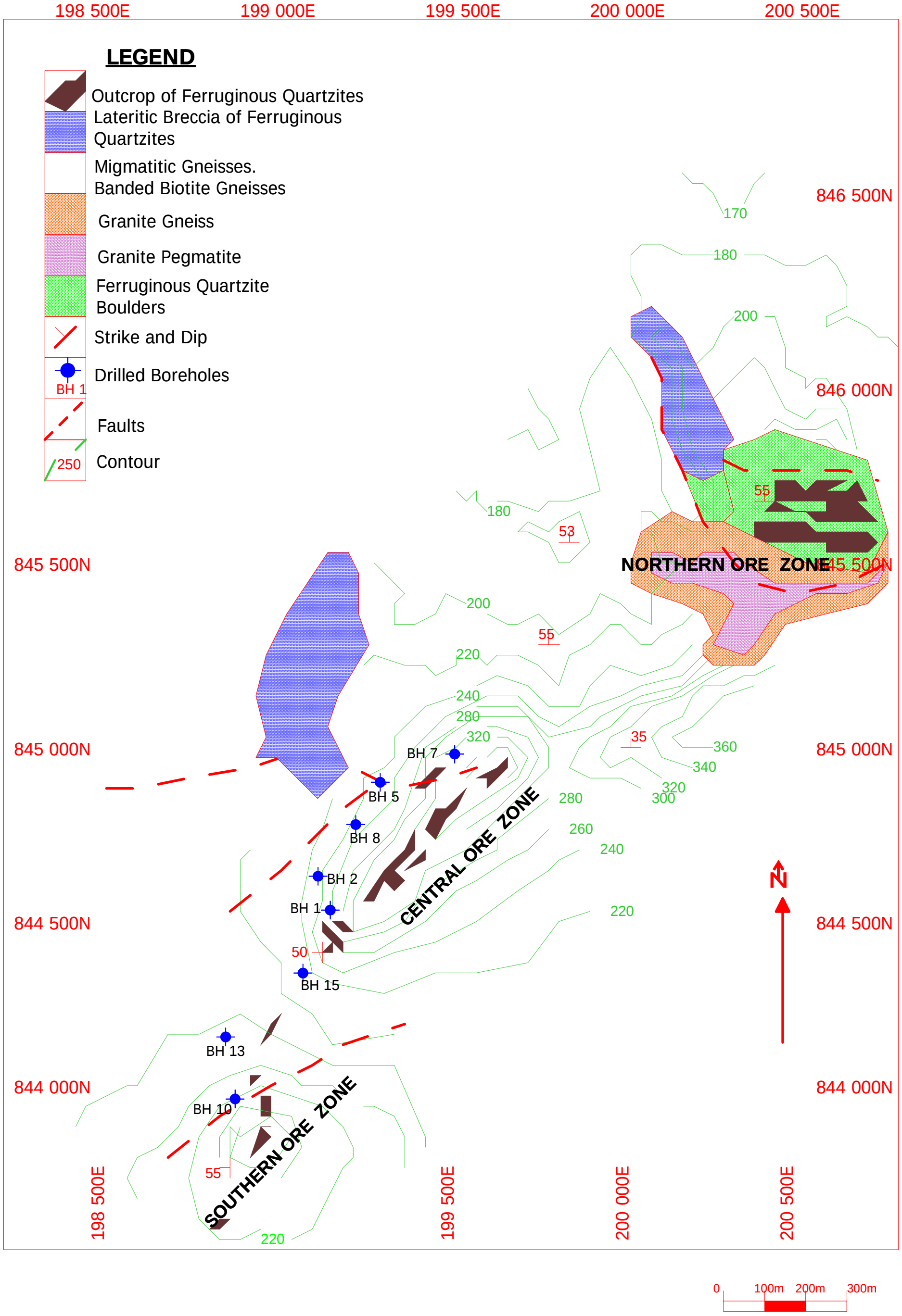

Figure 2: Geological Map of Ajabanoko Iron Ore Deposit (Adapted from National Iron Ore Mining Project, Itakpe).

The rock samples after twelve hour's saturation in water were first weighed in air using weighing balance and immediately after in water. From the measured weights, the densities of the rocks were determined. According to Dobrin and Savit (1988), the density of a substance is given as its mass per unit volume i.e.:

$$\text{Density } (\rho) = \text{Mass} / \text{Volume} \qquad \textbf{(1)}$$

This can be written as;

$$\text{Relative density (Rd)} = \frac{\text{Mass (or weight) of a substance}}{\text{Mass (or weight) of equal vol. of water}} \qquad \textbf{(2)}$$

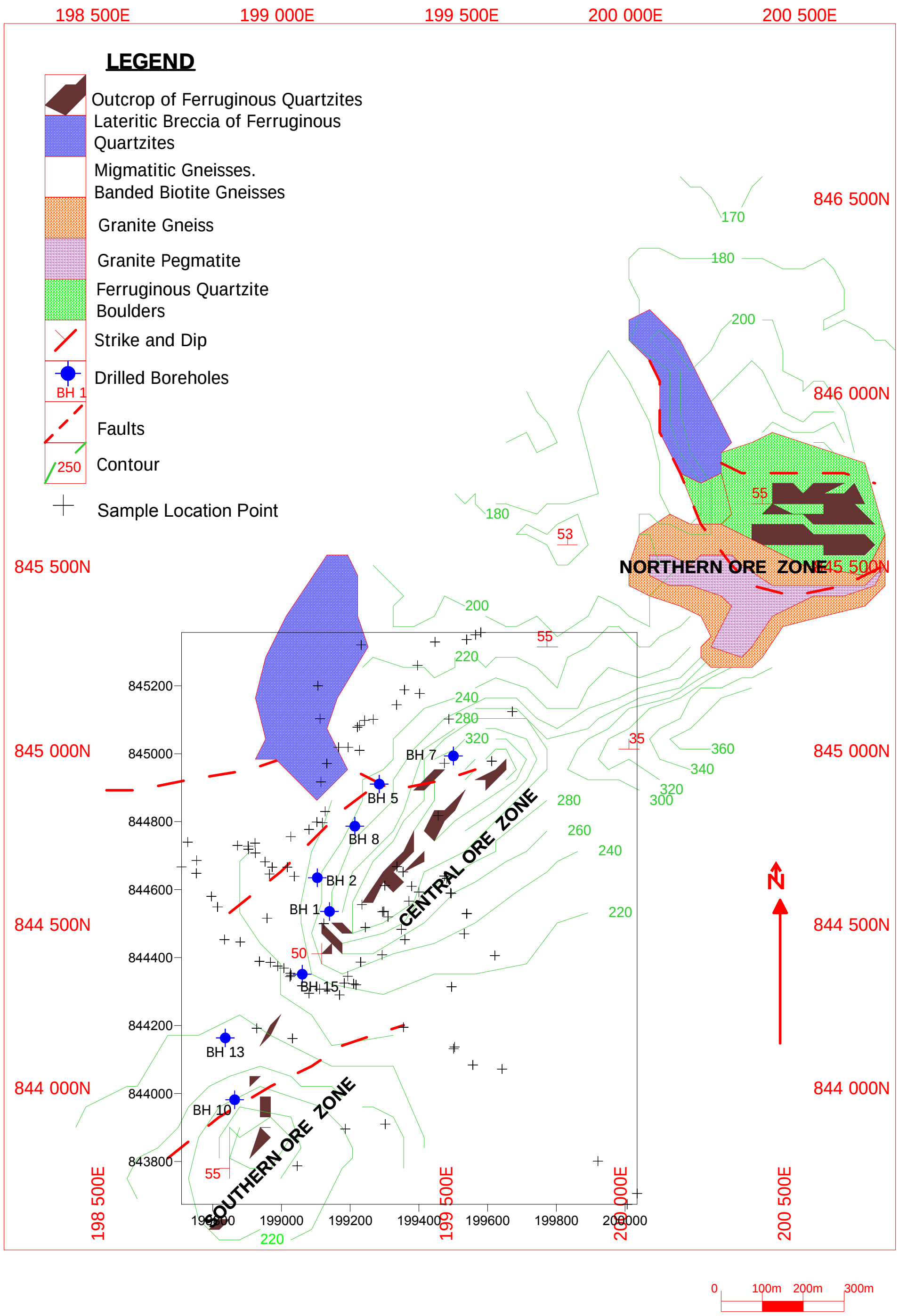

Figure 3: The Rock Sample Location Points over Ajabanoko Deposit.

The density of a substance is numerically equal to its relative density i.e. :

Density of rock sample =

$$\frac{\text{Mass of rock sample}}{\text{Up thrust on rock sample}} \times \text{Density of water} \qquad \textbf{(3)}$$

The density of water (ρ_w) at 4^0 C is approximately 10^3 kg/m^3, therefore Equation (3) can be expressed as:

$$\rho = \frac{M_1}{M_1 - M_2} \qquad \textbf{(4)}$$

Where, M_1 and M_2 are the mass of the sample in air and water respectively. Using Equation (3), the density for rock sample at location 13 in Appendix (Table 1) is computed thus:

$$\text{Density of rock sample} = \frac{25.0 \text{ (g)}}{(909 - 900) \text{ cm}^3} \times 1$$

$$\rho_{s13} = 2.8 \text{ g/cm}^3 \text{ or } 2.8 \times 10^3 \text{ kg /m}^3$$

Where, M_1 is 25g and upthrust is the difference between the volume of water before and after immersion. The density data shown in Appendix (Table 1) are presented as density map and also subjected to statistical analysis to determine the range of density values of major rock types in the study area.

DENSITY DATA ANALYSIS AND INTERPRETATION

The density map of the rock samples shown in Figure 4 describes the density distribution over the study area; the relative low and high density patterns identified on the map are qualitative representation of spatial variations in the density of underlying shallow crustal rocks which may signify lithologic change or conditional change of a particular rock type. The results from the laboratory density determination show that the iron ore of Ajabanoko deposit has a relative high density value (an average 3.8 x 10^3 kg/m^3) than the host migmatite and granite gneisses which have an average 2.5 x 10^3 kg/m^3. Using the density values, areas of relative high density values can be inferred as ferruginous quartzite zones (i.e. the areas marked (A) in Figure 5).

At the north central part of the study area, the equi-density contours show a northeast – southwest trend which coincides with an iron ore mineralization zone on the geologic map. Though a significant part of the north-eastern area was not covered due to difficulty of accessibility, the contours indicates that the ore at the north central is likely to continue in the eastern direction.

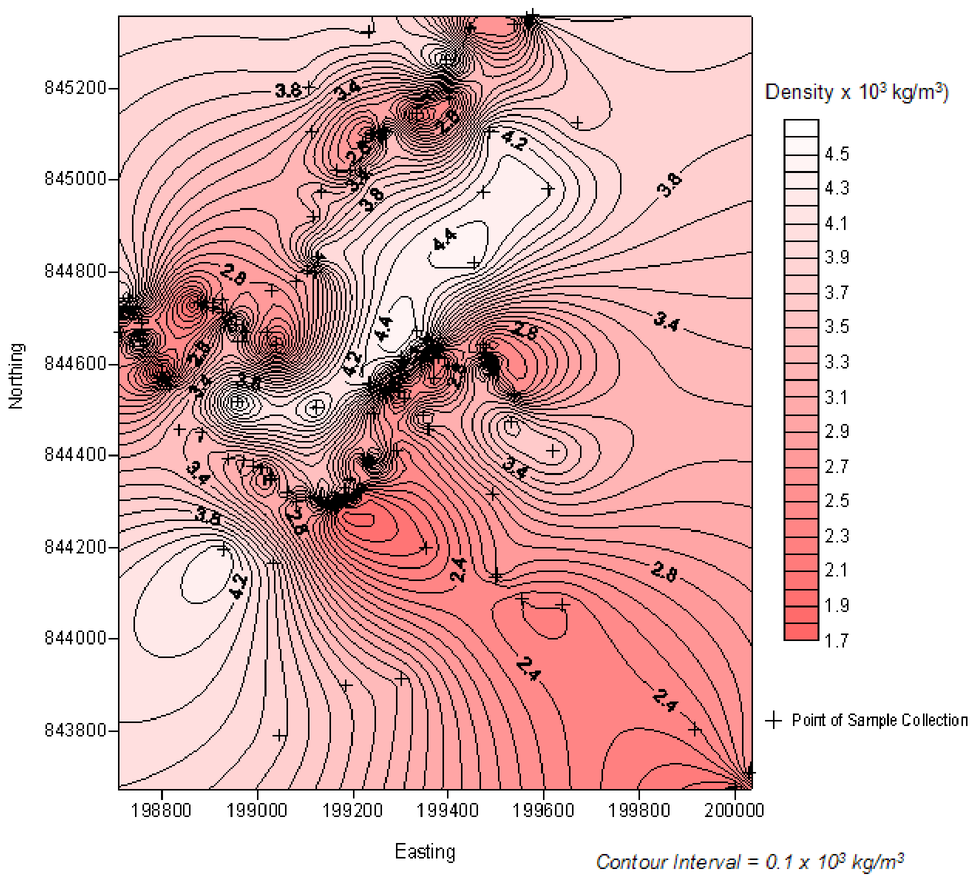

Figure 4: Rock Density Map of Ajabanoko Deposit.

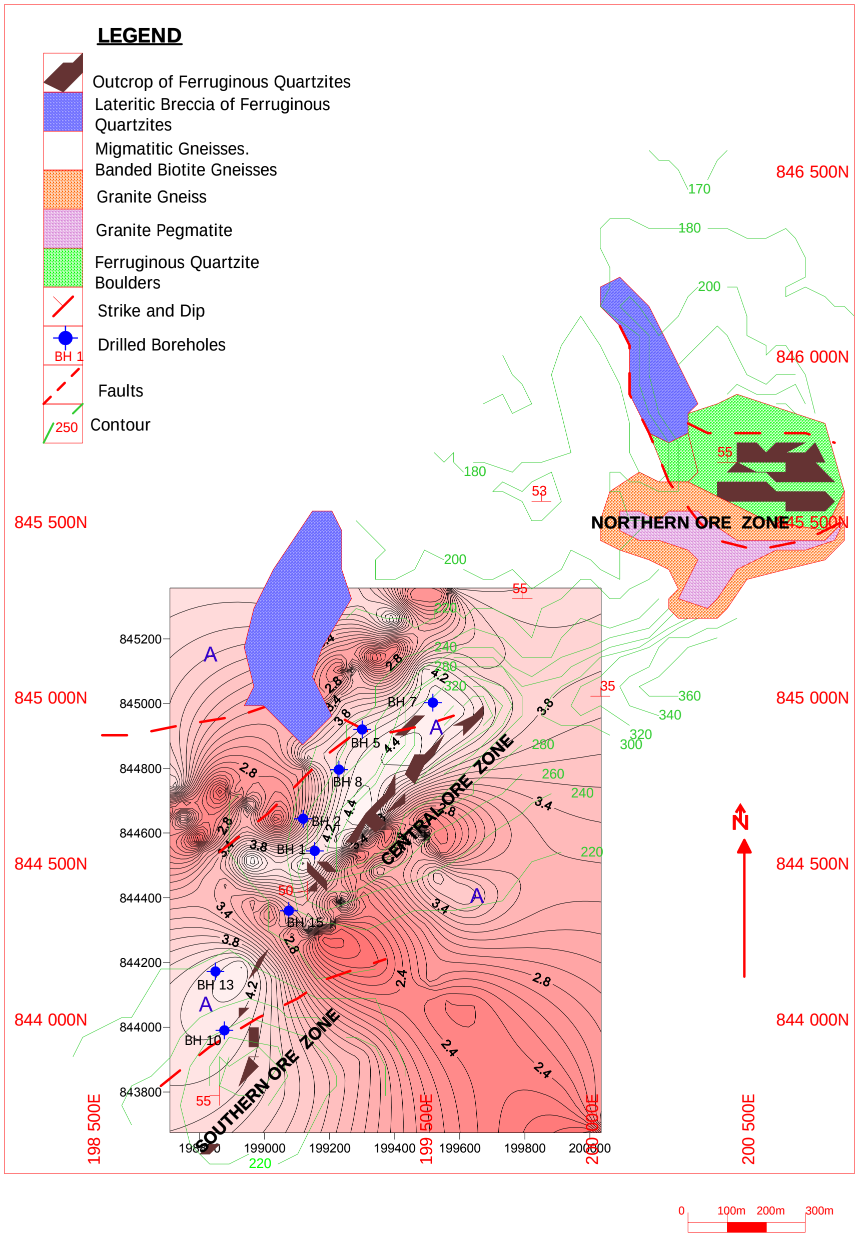

Figure 5: Map showing the Correlation of the Ajabanoko Density Map with the Geologic Map of the Area.

The statistical analysis of the density data has been useful in establishing the range of density values corresponding to the major rock types and the ore varieties typical of the ferruginous quartzite in the study area. Figures 6a - 6c show the histograms of the density of rocks of the study area.

Figure 6a shows the density distribution of the 109 rock samples with rocks density values in the range of 1.5 x 10^3 kg/m^3 to 3.0 x 10^3 kg/$m^3 \pm 0.8$ correlated with gneisses; while densities greater than 3.0 x 10^3 kg/$m^3 \pm$ 0.5 represent ferruginous quartzite. The determined mean density of 3.1 x 10^3 kg/m^3 ± 0.8 for the 109 rock samples in Figure 6a could not be accepted as representative mean density for rocks in the study area because of its standard deviation value of 0.79 which is considered too high.

Figure 6b shows that density value of 2.9 x 10^3 kg/m^3 ± 0.4 constitutes the highest frequency in the gneisses group while Figure 6c shows that there is a characteristic difference in the rock samples categorized under the ferruginous quartzite.

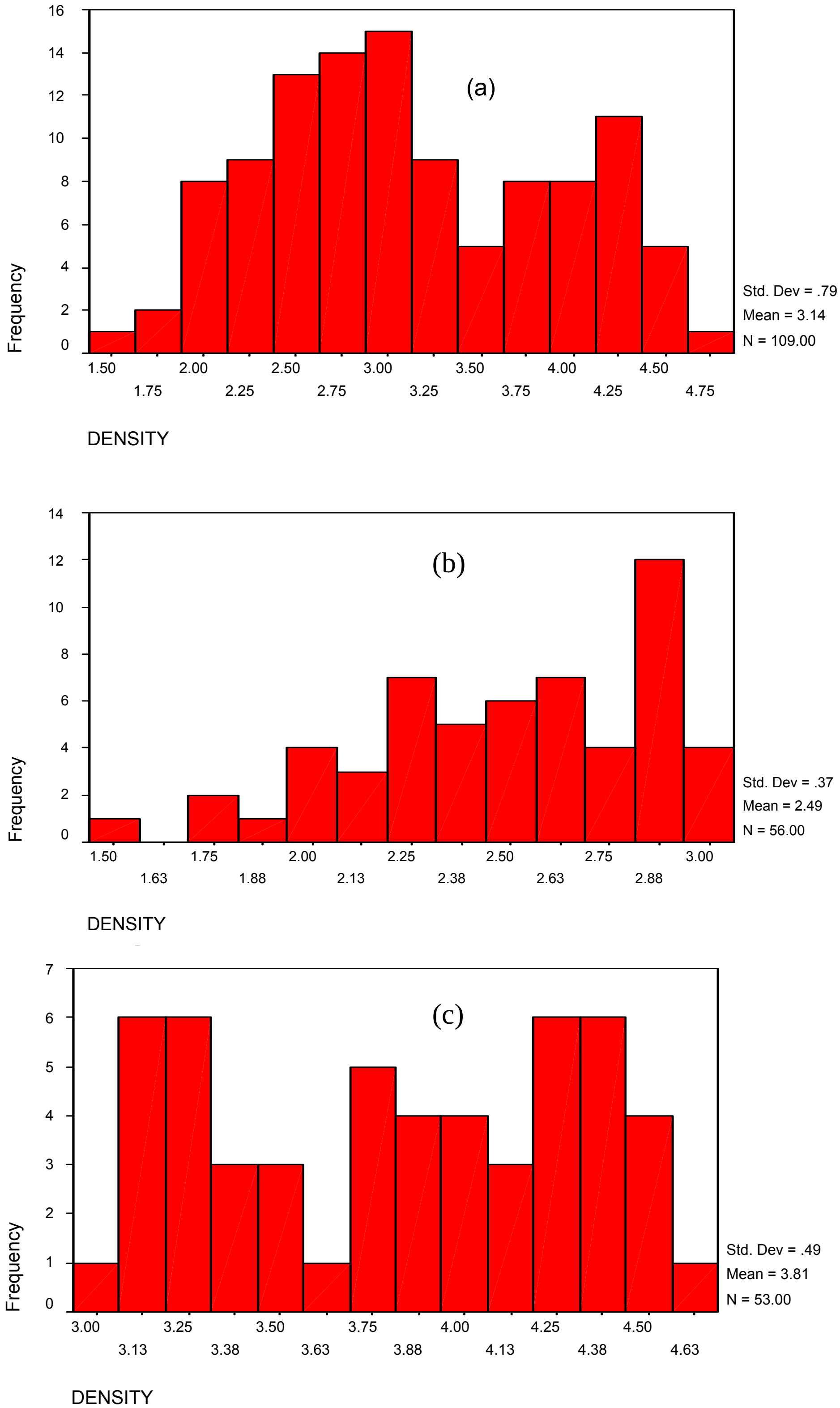

Figure 6: Histograms of Rock Sample Density Distribution at Ajabanoko Deposit:
(a) Total Rock Samples (b) Host Rock and (Gneisses) and (c) Ferruginous Quartzite (Iron ore).

This distinction was expressed by frequency peaks at density range 3.1 x 10^3 kg/m^3 – 3.3 x 10^3 kg/m^3 and 4.2 x 10^3 kg/m^3 – 4.4 x 10^3 kg/m^3 ± 0.5 which signifies magnetite and hematite ore respectively while the range between 3.3 x 10^3 kg/m^3 and 4.0 x 10^3 kg/m^3 suggests a mixture of the two ores.

The density results of core samples from three of the boreholes drilled in the study area by NSRMEA i.e. BH4, BH6, and BH9 confirmed that the gneisses in the area have density values ranging from 2.8 x 10^3 kg/m^3 to 3.0 x 10^3 kg/m^3 and the ore (magnetite and/ or hematite) from 3.1 x 10^3 kg/m^3 to 4.8 x 10^3 kg/m^3, this information corroborates the statistical analysis result in this study.

CONCLUSION

This study has shown that the laboratory density determination of rocks and its resulting analysis vis a viz as shown from the density contour map which reveals the density distribution of the underlying shallow crustal rocks in the area i.e. ferruginous quartzite and gneissic rocks, could be a useful tool for geologic mapping and prospecting of ore mineralization. Also, the result of the density analysis which indicates a range of 1.5 x 10^3 kg/m^3 to 3.0 x 10^3 kg/m^3 for gneissic rocks and above 3.0 x 10^3 kg/m^3 for ferruginous quartzite is adequate density contrast that favors the choice of gravity method for further exploration of the Ajabanoko deposit.

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APPENDIX

Table 1: Determined Density Data of Ajabanoko Deposit Area using Archimedes Principle.

Location	Northing	Easting	Weight in Air	Vol.(B. Immersion)	Vol.(A. Immersion)	Upthrust	Density
1	844323	199210	59.1	900	919	19	3.11
2	844320	199217	18.7	900	909	9	2.08
3	844345	199193	43.6	900	915	15	2.91
4	844325	199183	43.8	900	913	13	3.35
5	844290	199169	14.2	900	908	8	1.78
6	844307	199133	39.6	900	910	10	3.96
7	844307	199111	25.8	900	909	9	2.87
8	844295	199080	44.8	900	917	17	2.64
9	844317	199060	75.1	900	923	23	3.27
10	844344	199025	51.5	900	919	19	2.71
11	844348	199028	29.8	900	910	10	2.98
12	844354	199026	25.8	900	909	9	2.87
13	844369	199007	25	900	909	9	2.78
14	844375	198989	33.2	900	910	10	3.32
15	844386	198968	57.2	900	919	19	3.01
16	844389	198936	47.8	900	915	15	3.19
17	844446	198880	36	900	911	11	3.27
18	844453	198834	28.1	900	908	8	3.51
19	844549	198814	29.9	900	910	10	2.99
20	844580	198796	13.8	900	909	9	1.53
21	844648	198752	37.3	900	910	10	3.73
22	844667	198709	35.8	900	916	16	2.24
23	844740	198727	42.6	900	910	10	4.22
24	844686	198753	31.4	900	914	14	2.24
25	844730	198872	15.5	900	909	9	1.72
26	844728	198903	20.5	904	911	7	2.93
27	844719	198904	28.3	900	911	11	2.57
28	844737	198923	21.4	900	908	8	2.68

Table 1 (Continued): Determined Density Data of Ajabanoko Deposit Area using Archimedes Principle.

Location	Northing	Easting	Weight in Air	Vol.(B. Immersion)	Vol.(A. Immersion)	Upthrust	Density
29	844708	198924	23.5	900	910	10	2.35
30	844682	198952	39.2	910	920	10	3.92
31	844666	198973	25.8	900	909	9	2.87
32	844666	199017	37.9	900	915	15	2.53
33	844639	199037	32.4	900	916	16	2.01
34	844756	199027	21.8	900	908	8	2.73
35	844777	199080	29.6	901	911	10	2.96
36	844799	199103	65.4	900	921	21	3.11
37	844797	199119	32.6	900	910.5	10.5	3.11
38	844830	199127	57.3	908	922	14	4.09
39	844917	199115	25.8	900	908	8	3.23
40	844971	199132	35.1	902	912	10	3.51

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