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RELATIONSHIP BETWEEN THE GENETIC AND SOME BENEFICIATION CHARACTERISTICS IN THE FERRUGINOUS QUARTZITES OF ITAKPE HILL NIGERIA

C. K. OBASI and L. A. OBASI

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ABSTRACT

A clear and direct relationship existing between the compositional parameters and beneficiation indices was revealed through laboratory beneficiation, of the ferruginous quartzites of Itakpe Hill using magnetic methods. The heterogeneity in the formation of the quartzites in different parts of the deposit was reflected in the results if their beneficiation. The genetic factors affecting the beneficiation indices were identified, among which the leading role fell on the mineral form of iron. The Fe content to a large extent determines the yield and recovery. A function of the total iron contents in the quartzites (Fe_{total}), iron contents of magnetite (Fe_{mgt}) and the beneficiation indices (defined here as the productivity) of the ferruginous quartzites served as a basis for their mineralogic-technological classification. The inconsistent tendencies in the productivity was seen to correspond to an earlier established mineralogic-geochemical zoning within the deposit.

Keywords: Relationship, genetic features, beneficiation indices, ferruginous quartzites.

INTRODUCTION

Earlier pilot beneficiation studies on the ferruginous quartzites of Itakpe Hill (Bogdanova and Radchenko, 1976; Uwadiale and Odunaike 1991) revealed the following:

1.- the ferruginous quartzites are composed of haematite quartzites (Fe- 42%), haematite magnetic quartzites (Fe - 38.45%), magnetite-haematite quartzites (Fe - 32.96%), and magnetite quartzites (Fe- 36.81%);

2.- over 90% liberation of the ore minerals is attained at a grain size of -0.63mm, and complete liberation at -0.16mm;

3.- the physico-chemical properties of the ferruginous quartzites are enhanced by their self-crush methods;

- two major technological types of ferruginous quartzites were distinguished, viz - magnetite quartzites (the beneficiation of which is best done by magnetic methods in a weak magnetic field), and haematie quartzites (which is best beneficiated by gravitational methods). Intermediate (magnetite-haematite and haematite-magnetite) quartzites in a proportion of 60:40 could be beneficiated by a combination of gravitational and magnetic methods;

4.- this approach to the beneficiation of the ferruginous quartzites gave recoveries of between 84.5 to 91.5%, with the Fe content of concentrates in the range of 66 to 69.2%.

From the above it can be seen that the earlier investigations only gave a general insight into the beneficiation parameters of these quartzites, showing that they could be used as raw materials in the iron and steel industry. Classification of the quartzites on the basis of their beneficiation parameters was not carried out, nor were the mode of changes in the beneficiation parameters, the spatial distribution of the technological types within the deposits, and their relationship to mineralogical and genetic peculiarities examined. These problems arise with the mineralogic-technological mapping which is aimed at a more detailed evaluation and utilization of the ferruginous quartzites at Itakpe Hill. Therefore the need to study mineralogic-technological peculiaries of the quartzites to delineate the geologic-technological groupings and types , on the basis of their genesis cannot be over-emphasized.

The approach used in this work is based on the concepts for identifying the relationahip between the mineralogic-genetic properties of ores and their technological parameters [Pirogov, 1987'. These concepts indicate that:

- the technological properties of ores (crushability, grindability, liberation, separation of liberated materials, behaviour of products in the blast-furnance, etc) have a direct link with the genesis; since fabric, texture and other physico-chemical properties are a resultant of the particular condiction of ore formation;
- the fabric, texture, mineral assemblage, mode of intergrowth between the ore and non-

C. K. OBASI, Department of Geology and Mining, University of Jos, Jos - Nigeria
L. A. OBASI, Department of Geology and Mining, University of Jos, Jos - Nigeria

ore minerals (for example - inter-penetration, morphology, nature of inter-growing boundaries, the cohesive forces) determine the effectiveness of crushing and grinding; processes such as flotation significantly depend, among others, on morphology, distribution, inclusions, defects and electro-physical properties, of the mineral grains;

- the technological properties of minerals have a dual nature. On one hand, they determine the link of the constitution and morphology of minerals with their genesis, and on the other hand, the changes in morphology and constitution, and consequently, their natural properties in the preparatory stages of beneficiation;

- the technological properties of minerals occur in a wide range of ordinary and technological granulometry;

- the geologic-technological mapping of deposits on the basis of typomorphic features, and dressability minerals allows direction (control) of the beneficiation process and forecast of the expected technological parameters. So every deposit needs to be studied seperately and the factors that determine the dressability of its ores identified.

This study takes into account an earlier demarcation of the deposit into three genetic zones [Pirogov and Obasi, 1991a] on the basis of several typomorphic features (mineral and chemical composition) of the ores. It was noticed that, the eastern part of the deposit owes it origin to granulitic metamorphic facies, while most of the central and western parts are the amphibolite metamorphic facies, and the north-central parts have been affected by post-intrusive alkaline metasomatism. A gradual decrease in the magnetite content of the quartzites was observed in these directions. Apart from that, within the individual ore-bodies a gradual transition from exclusively magnetite quartzies along the hanging and foot-walls to exclusively haematite quartzite in the centre of the ore-bodies was observed. Since magnetite is the most widespread ore-mineral, occuring in all the genetic zones, as well as in almost all the ore types it is then logical and convenient to use its genetic properties and behaviour during magnetic beneficiation to illustrate this genetic-technological relationship. The magnetic method was preferred for this, since it does not alter the genetic properties.

ANALYTICAL METHODS

Beneficiation was carried-out on 45 small size representative smaples (1-3kg each) of all the different mineralogical types under laboratory conditions. On each sample preliminary detailed studies were carried-out on the mineral phase, and chemical composition, the distribution of the various mineral-forms of iron, the fabric and textural peculiarities - the morphology, granulometry of grain and aggregates of the major minerals, their mode of occurrence, and types of intergrowth among them. The anatomy of the minerals was also studied both after acid etching and by electron microscopy. The chemical compositions of the samples and the composite minerals, their optical properties (reflectively, refractive indices, etc) physical (hardness, electrical, thermal, magnetic) and other properties which affect dressability of the ores, were examined and analyzed using a suite of modern physico-chemical methods {Pirogov and Obasi 1991b].

On the basis of recommendations made by earlier studies [Uwadiale and Odunaike. 1991], wet magnetic seperation was used. The preparation of the samples involved preliminary crushing and grinding, with occasional screening to follow-up the degree of liberation, avoid over-grinding (which could cause flocculation and morphotropic changes) and control the size of the ground material. The ground material was mixed into a paste, then in a stream of clean water run through the Davies Tube twice - first through an electromagnetic field of about 1000-1300ergs, then later repeated in a field of 500-700ergs. The concentrates and tailings obtained were each dried, reweighed and analyzed.

The degree of liberation and effectiveness of separation of the ore minerals were evaluated in the concentrates under the microscope. The yield, recovery, and iron contents of the concentrates and tailings were determined, both through calculations and chemical tests. Mathematical and statistical methods were widely used to establish relations (both paired and multiple) between the mineralogic-genetic (compositional) peculiarities and the beneficiation indices of the ferruginous quartzites.

RESULTS AND DISCUSSION

Observations under the microscope revealed that the ferruginous quartzites of Itakpe Hill posses a very high degree of aggregation (between 80 to 90%), which enhances the coarse- and medium-grained texture of magnetite, and consequently its easy liberation. This is the result of high grade metamorphism to which the quartzites were subjected, and in the course of which magnetite grains underwent some degree of cleansing from internal impurities during recrystallization. The observations also explain the quality of the concentrates obtained. In the silicate-magnetite (pyroxene- and amphibole magnetite) quartzites which show a lower degree of aggregation among the magnetite grains there was also a lower degree of ore-grain liberation due to the poikilitic intergrowth between magnetite and the silicates. This, of course reflected on the beneficiation indices - a decrease in the Fe recovery, and an increase in the Fe contents of the tailings. The reduction in the Fe contents of the concentrates can be attributed to the presence of defects and impurities observed by examining the anatomy of magnetite grains.

The generalized results obtained through beneficiation of the quartzites are shown in Table.I. It can be seen that the inconsistency of the beneficiation indices corresponds closely with the genetic peculiarities of the quartzites i.e with the mineralogic-genetic zoning of the deposit.

On the basis of recovery (Σ) three technological groups were distinguished poor recoveries (10-35%), intermediate recoveries (35-65%), rich recoveries (65-100%), marked by the peaks in the distribution (Fig I).

A more complete and objective mode of evaluating the technological mineralogy, used in this work is through the productivity. Productivity, here us regarded as a function of the mineralogic-genetic characteristics (Fetotal, Fe in magnetite, Fe non magnetic,) and the beneficiation indices (yield, recovery, Fe contents of the concentrates and the tailings) of the quartzites. This formed the basis for the classification of the quartzites in the Tab. I,

As had been earlier established, the Fe contents of the ferruginous quartzites in different parts of the deposit have direct dependence on the genesis - the retrograde tendencies in the evolution enhanced the remobilization of Fe as ore-minerals. The effect of this on the beneficiation indices is well illustrated in Figs, 2, 3, and 4, through the dependence of such parameters as recovery and Fe contents of the concentrates on the overall Fe contents of the quartzites. These diagrams clearly show that the beneficiation indices of the quartzites which have undergone metamorphism differ considerably from those that have been affected by metasomatic processes. The superimposition of histograms of distribution within the various genetic types (Fig. 3) indicates this difference: Mgt I and Mgt II have their peaks shifting to the right while the curve of Mgt III is hyperbolic. In Fig. 4 also, the histograms clearly distinguish three preferred concentrations. All these clearly reflect the heterogeneity and directional tendencies in the mineral formation processes (from metamorphism, first under granulite facies, then amphibolite facies, intrusion of granitic material and metasomatism) which the ferruginous quartzites have gone through. These geological processes caused changes in the properties of the quartzies and their composite minerals, which then predetermined the beneficiation indices of the ferruginous quartzites.

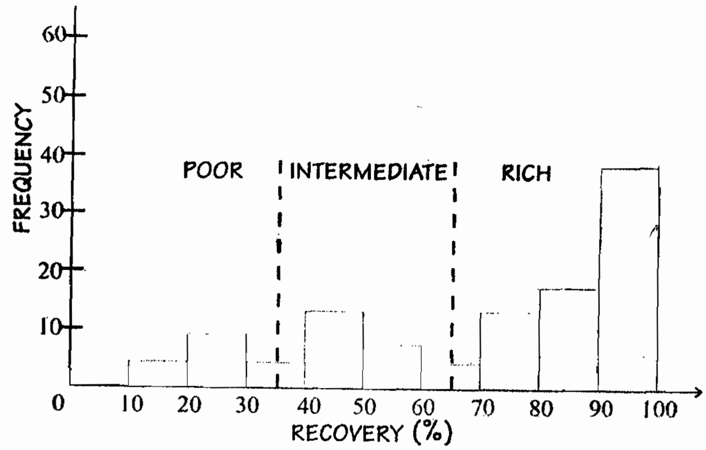

Fig.1 Distribution of Fe recoveries in the concentrates

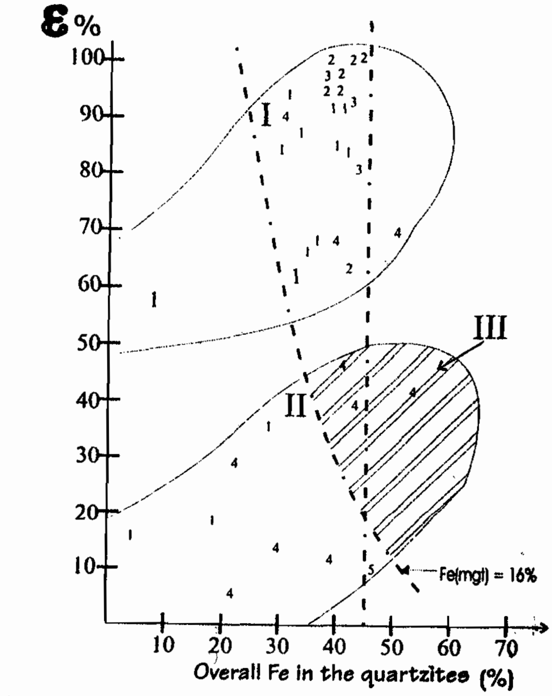

Fig.2: Relationship between Fe in the ferruginous quartzites and its recoveries. Recovery parameters from: 1 - pyroxene-amphibole-magnetite quartzites; 2 - magnetite quartzites; 3 - haematite-magnetite quartzites; 4 - magnetite-haematite quartzites; 5 - haematite quartzites. Quartzites from: I - zones associated with metamorphism; II - zones associated with metasomatism; III - highly Fe-enriched zones.

Both paired and multiple correlation analysis of the obtained results showed very high coefficients between the beneficiation indices (yields, recovery, Fe contents of the concentrates), on one hand, and the genetic/compositional parameters (Fe, Femgt), on the other.

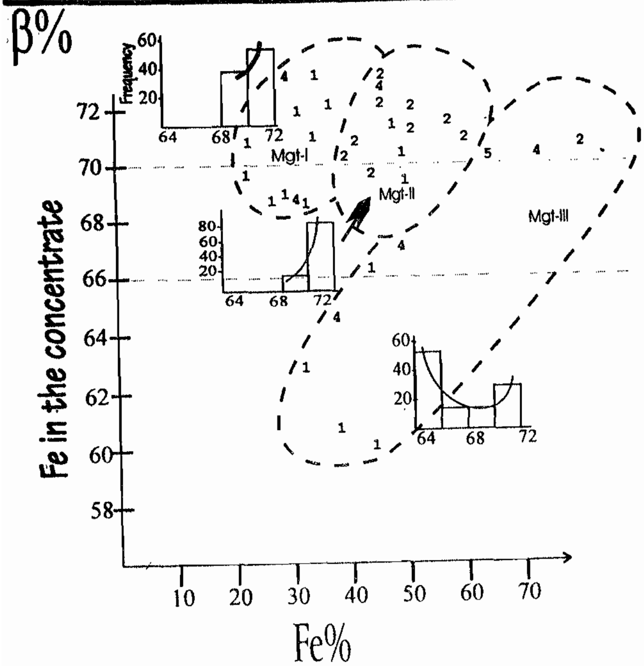

Fig.3: Relationship between Fe in the ferruginous quartzites and Fe in the concentrates Legend as in Fig.2.

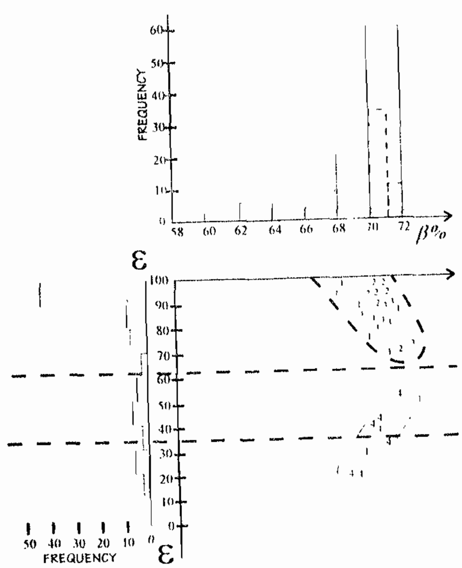

Fig 4 Relationship between the Fe contents of the concentrates and the recoveries or Fe from the ferruginous quartzites Legend as in Fig.2.

Since the mineral magnetite can be presented as $FeO.Fe_2O_3$ and haematite as Fe_2O_3, definite relations have been established between their composition in ferruginous quartzites (Pirogov and Pirogova, 1973), through ε magnetic modulus;

$$Km = Fe_{mgt}/Fe \quad (1)$$

an oxidation modulus;

$$Ko = Fe_2O_3/FeO + Fe_2O_3 \quad (2)$$

and the relationship

$$Fe_2O_3 = [FeO \times 0.778] \times 1.43 \quad (3)$$

Fe_{tot}, Fe_{mgt} and FeO were determined by laboratory methods.

Also, the following relationship exist between beneficiation parameters and the overall Fe in the ferruginous quartzites (which is dependent on the ore formation conditions).

$$Y.\beta = \Sigma.Fe_{tot} \quad (4)$$

where Y, is the yield Σ is the recovery, β is the Fe contents of the concentrate. It then transpires that a relationship exists between the initial compositional properties of ferruginous quartzites and their beneficiation parameters. Due to the inconsistency of the magnetite /haematite proportion in the examined ferruginous quartzites equation 4 then obtains only for cases in which magnetite is the sole Fe mineral phase present, rendering it unacceptable for forecasting beneficiation parameters in the partially oxidized ferruginous quartzites. Taking into consideration experimentally obtained results the authors then established the relationship between compositional and beneficiation parameters through equations of multiple correlation.

This allowed derivation of the following equations of multiple regression for the technological evaluation of the ferruginous quartzites:

$$Y = 13.53 + 0.35Fe + 0.23Fe_{mgt} - 0.35FeO + 53.14Km \quad (5)$$

$$\Sigma = 3.48 - 0.064Fe + 0.09Fe_{mgt} + 0.29FeO + 86.6Km \quad (6)$$

$$\beta = 65.58 + 0.039Fe_{mgt} + 0.038\Sigma \quad (7)$$

where Y, is the yield, Σ is the recovery, β is the Fe contents of the concentrates, Fe_{mgt} is the percentage of the iron which goes to magnetite, Km is the magnetite modules, i.e Fe_{mgt}/Fe. The above equations can be used to successfully (95% probability) forecast the beneficiation indices of the ferruginous quartzites at Itakpe Hill, using magnetic methods.

In zones affected by granulite facies (eastern parts) there is a gradual increase in productivity (intermediate to high) from the quartzites in the hanging- and foot-walls towards the centre of the orebodies. Whereas in the other parts of the deposit productivity first of all increases, (from intermediate to very high), then gradually falls (to low) towards the centre of the orebodies, as a result of the occurrence of non-magnetic, haematite quartzites. These tendencies are in accordance with the earlier revealed mineralo-geochemical zones within the deposit.

The foregoing allowed emphasizing that the genetic peculiarities of the ferruginous quartzites determine their dressability. Among those identified (Tab.2) Fe and Fe_{mgt} are the

Table I. Mineralogic-technological classification of the ferruginous quartzites of Itakpe Hill

Mineral types of the ferruginous quartzites	Evaluation of productivity								Technological ore groups
	Fe (total) %	Fe_{mgt}%	Km	Ko	Yield%	Fe (concent) %	Recovery %	Fe (tailings) %	
Pyroxene-amphibole magnetite quartzites	28.6±1.9	22.7±2.6	0.45-0.85	<0.69	37.4±3.6	68.6±0.6	75.6±5.0	6.4±0.6	High productivity
Magnetite quartzites	38.7±4.3	36.6±2.5	0.85-1.0	0.5-0.8	56.4±2.8	70.6±0.2	94.9±1.9	1.9±0.3	Very high productivity
Haematite-magnetite quartzites	34.6±2.9	18.0±5.2	0.45-0.85	0.7-0.9	50.2±4.9	71.3±0.2	89.4±4.0	7.7±2.8	Moderate - high productivity
Magnetite-haematite quartzites	38.5±3.1	10.2±3.0	0.2-0.4	0.85-0.95	19.4±4.1	69.0±0.8	41.9±6.3	26.7±3.1	Moderate productivity
Martite-haematite quartzites	40.5±3.9	4.8±3.0	0.02-0.2	09.-0.96	14.0±0.8	69.8±0.5	21.5±2.3	38.3±3.3	Low productivity

$Fe_{(mgt)}$- Fe magnetite in the ores; Km - Fe/$Fe_{(mgt)}$); Ko=Fe_2O_3/Fe_2O_3 + FeO.

mostdeterminant factors in this case. It is the view of the authors that productivity forms a more reliable means for the technological evaluation of ores, than that used by earlier investigators. Maps of the deposit at various horizons can thus be obtained which will, no doubt, give a rational approach to exploitation and beneficiation with known expected results.

CONCLUSIONS

The major mineral associations, fabric, textural features, and phase distribution of Fe in the mineral types are all closely connected to the mineralo-geochemical zoning of the deposit. So in the eastern parts of the deposit the orebodies are highly productive, while in the other parts productivity decreases towards the centre of the orebodies from the viewpoint of magnetic methods of beneficiation. Thus a clear dependence of the beneficiation indices on compositional paremeters is revealed. This is a consequence of the particular condictions of ore formation; a relationship which was carried on further to the behaviour of the ferruginous quartzites during beneficiation. The establishment of this link is an indication that there is a need for intensified geologic-technological re-evaluation and mapping of ferruginous quartzites. It is the authors' view that these findings will go a long way to help solve the ore dilution problems facing the beneficiation plant at Okene, and also improve production, since it gives a more accurate information for directed exploitation of the various ore types within the deposit. This work clearly shows that the present blending of the various ore types before beneficiation should be discouraged, while preferably, selective

Table 2. Typomorphic features which determine the dressability of the ferruginous quartzites of Itakpe Hill.

Typomorphic features	Technological Peculiarities
1. Changes in the mineral forms of iron [Fe(total), Fe_{mgt}, Fe(non-mgt)] due to mineralo-geochemical zoning of the bodies.	Determine quantitative indices during beneficiation (yield, recovery, Fe contents of the concentrates and tailings), their tendencies and, in general the productivity of the various mineralo-technological groups.
2. Morphology, granulometry, types of intergrowth between magnetite and the other minerals, homogeneity of the magnetite grains (chemistry, structure, properties etc).	Determine the degree of liberation of the magnetite grains during grinding and crushing of the ores, as well as the quality of the concentrates.
3. Haematite generations and their intergrowthwith magnetite and other minerals.	Determine the major cause for the loss of Fe in magnetite method of beneficiation and the rationale in the choice of gravitational flow chart (rich ore intergrowths between magnetite and haematite (martite) increases the Fe contents of the concentrates and a loss of Fe to the tailing)
4. Composition of the non-ore minerals (pyroxenes, mica. etc).	Determines the effectiveness of liberationof non-ore minerals during crushing by partial dilution of concentrations; of Fe to the tailings.

exploitation be employed to see if this will improve on the recovery of Fe from the quartzites.

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