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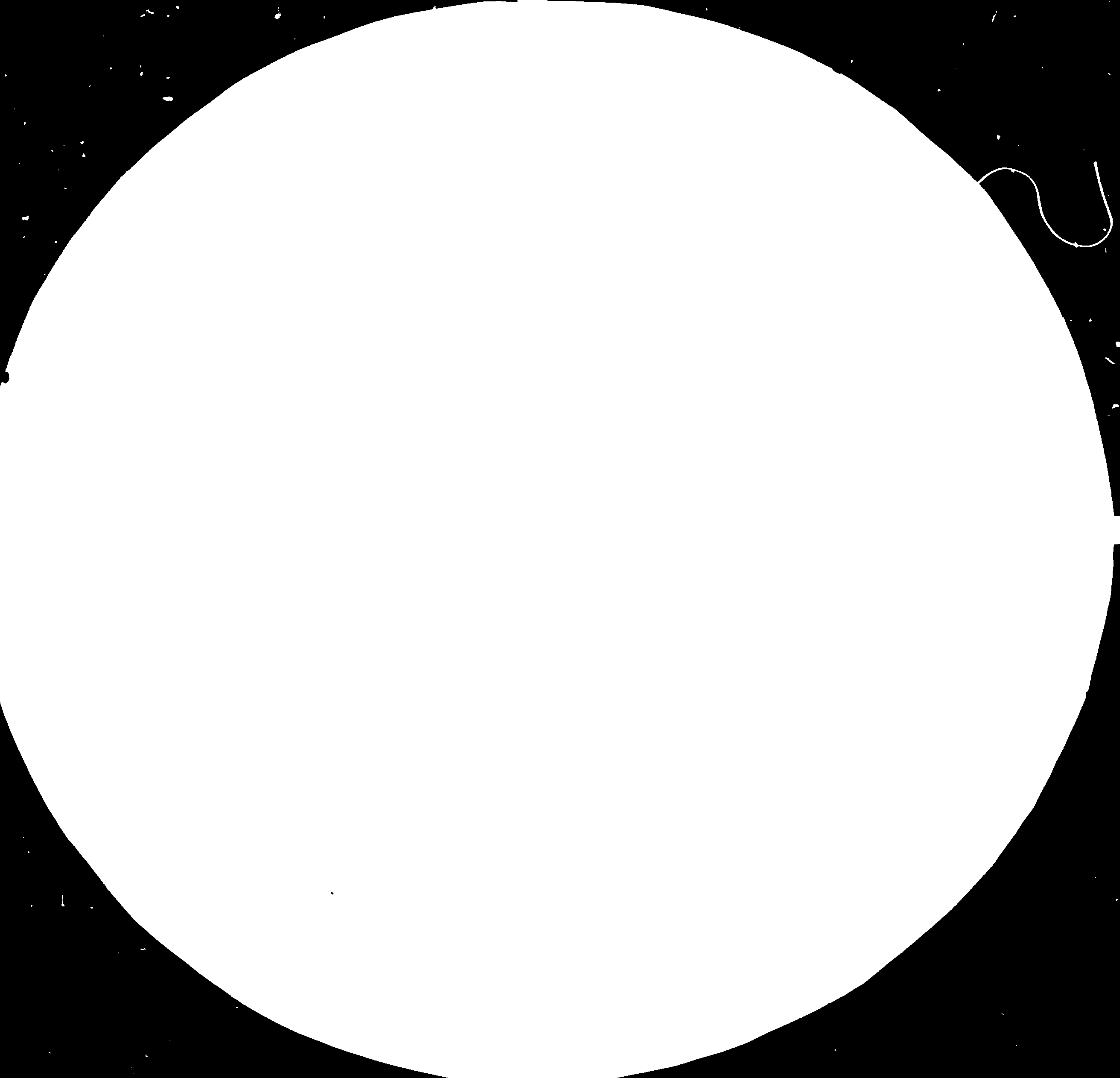

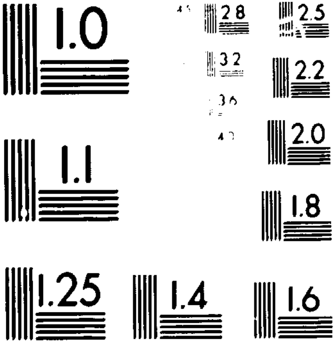


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS

STANDARD REFERENCE MATERIAL 1010a

(ANSI and ISO TEST CHART No. 2)

14510-E

Niger.

Addendum

to the

Final Report

of the

Preliminary Study of the Iron Ore Deposits at Say

Republic of Niger DP/RAF/79/067

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Date Jan. 1985

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August 1984
English

EVALUATION

OF THE PRELIMINARY STUDY

OF THE IRON ORE DEPOSITS

AT SAY REPUBLIC OF NIGER

prepared by

KHD HUMBOLDT WEDAG AG

UNIDO PROJECT DP/RAF/79/067

Elaborated by Viktor Sosic

Technical Adviser for Processing of Iron Ore

U N I D O

VIENNA

## IRON ORE DEPOSITS DOGUEL KAINA AND KOLO.

1. Ore reserves.

The iron ore deposits Doguel Kaina and Kolo, close to SAY, are located 30 to 40 km south-east of NIAMEY, Niger.

Oolothic ore occurs in three horizons:

- Upper horizon with iron oolithes "indurées",

| | |
|---|---|
| Fe-content average | 46...51 % |
| Thickness average | 2,20...2,53 m |

- Intercalation with oolith-bearing sands and clays

| | |
|---|---|
| Fe-content average | 24...33 % |
| Thickness average | 1,1 m |

- Bottom horizon with iron oolothes "tendres"

| | |
|---|---|
| Fe-content average | 43...46 % |
| Thickness average | 2,0...2,9 m |

The average overall thickness of the ore horizons amounts to 6,56 m.

1.1 Doguel Kaina.

| | |
|---|---|
| The total ore reserves in the Doguel Kaina area amounts to | 1.009 Mt |
| Average Fe-content | 45,73 % |

| | |
|---|---|
| Assuming a cut-off of 35%Fe for Intercalation horizon, the total ore reserves amount to | 937 Mt |
| with an average Fe-content | 47,44 % |

1.2 Kolo iron ore deposit.

| | |
|---|---|
| The total ore reserves amount to | 207 Mt |
| with an average Fe-content | 40,81 % |

Assuming a cut-off of 35% Fe, the total ore reserves amount to 173 Mt
with an average Fe-content 44,67 %

1.3 <u>Advantages of the iron ore deposits Doguel kaina and Kolo</u>.

- Large ore reserves.
- Iron mineral is goethite which is easy reducible.
- Open pit mining.

1.4 Disadvantages of Doguel Kaina and Kolo ore deposits.

- Relative high ratio overburden/ore.
- High silicious ore, practically without CaO and MgO.
- Due to impurities in the oolithes, this type of ore is possible to concentrate only up to 54 $\pm$1 %Fe.
- Low concentration of iron ore per $m^2$, i.e.only about 17 $t/m^2$ and therefore it is always necessary a long internal transport from open pit to beneficiation plant which requires high transport cost.
- Remote location, i.e.about 900 km from the sea port which excludes any export possibilities.

1.5 By means of an appropriate, simple and cheap beneficiation method concentrated oolothic ore, could be a very cheap raw material for a domestic steel industry.

2. <u>Project Work Plan - PWP</u>.

The detailed PWP has included all necessary works and tests:

- To identify the quality and quantity of the iron ore reserves.
- To asses techno-economically the beneficiation characteristics of the ore, including iron recovery and quality of concentrates.
- To assess techno-economically the pelletization characteri-

stics of the concentrates and direct reduction characteristics of the pellets.

I have to emphasise that the Contractor - HUMBOLDT WEDAG - has carried out this PWP very carefully and exemplary. All above mentioned problems have been successfully solved and optimal possible results have been obtained.

## 2.1 Beneficiation tests.

Crushing, grinding and beneficiation tests have surely proved the following:

- Recoverable Fe is concentrated only in oolithes.

- The emphasis has been put on maximum possible concentration of the iron mineral and 50 pure oolithes from each sample have been mannually separated after attrition.
  The chemical analyses of the individual oolithes of
  - sample 1 yielded an Fe-content of 54,21 % and
  - sample 2 yielded an Fe-content of 53,4o %

- Quartz grains are mainly smaller than 0,63mm - see B.4.1 !

- Due to very fine impurity inclusions in the structure of oolithes, the fine grinding of oolithes and HIWMS is not giving a higher concentrate quality in comparison with quality of concentrate /-3 + 0,5/mm, i.e.optimal beneficiation results could be obtained only by liberation of oolithes.

- Screen analyses of the crushed oolithic ore are no doubt an approval for the above mentioned statements.

  The most characteristic are screen analyses for sample 2, i.e.oolothes tendre - see Annex C-4 and C-6:

| Fraction | %W | %Fe | %R | $\%SiO_2$ | %R |
|---|---|---|---|---|---|
| + 5 mm | 23,4 | 41,9 | 22,9 | 18,6 | 24,6 |
| -5 + 3 mm | 3,6 | 42,6 | 3,5 | 18,o | 3,7 |
| -3 + 2 mm | 10,1 | 50,1 | 11,8 | 8,7 | 5,o |
| -2 + 1 mm | 31,2 | 50,1 | 36,6 | 7,9 | 14,2 |
| -1 + 0,5 mm | 17,3 | 43,6 | 17,9 | 17,2 | 17,4 |
| -0,5 mm | 14,2 | 21,6 | 7,2 | 43,1 !! | 36,1 |
| Feed | 100 | 42,7 | 100 | 17,4 | 100 |

Grinding results of sample 2 are a proof that beneficiation of oolithic ore - regardless of feed Fe-content - could be successful only by liberation of oolithes, i.e.by grinding on 100% -3mm, resp.according to screen analyses on -2,5mm, including the attrition/abradding of the matrix on the surface of each oolithe.

The above mentioned statement is valid also for oolithic intercalation horizon, with an Fe-content below cut-off limit of 35 %Fe.

Phosphorus problem.

All attempts to separate or to decrease P-content have failed and therefore in the steel plant a dephosphorization of the pig iron should be provided.

## 2.2 Crushing-grinding-attrition.

For desintegration of the oolithic ore contractor has used
- hammer crusher,
- hammer mill and
- attrition.

Regardless on the type of ore - indurée or tendre - by this equipment is possible to beneficiate the oolithic ore /-3+0,5/mm practically to the limit, i.e.53...54%Fe, what is a good result taking into account that a pure goethite - without impurities in the oolithes - has theoretically a content of 62,8 %Fe.

These results have been obtained only by separation of the soft matrix between oolithic grains by crushing/grinding and
by abradding of the matrix residue from the oolithe surface during attrition process and
by washing the adhering clay particles.

I have no comments concerning above mentioned equipment during beneficiation tests.
Meanwhile taking into account that hammer mill crushing gives considerable quantity of crushed oolithes and
that attrition of oolithes is a very important process phase, I recommend for fine grinding - instead of a hammer mill - an autogenous mill with peripheral discharge, as it is KRUPP PERIMILL.

An autogenous PERIMILL closed circuit grinding has many advantages:

- Extremely sharp control of size grinding which should be according to screen analyses decreased on 2,5mm.
- During grinding, the attrition of liberated oolithes is continuously present.
- Dry attrition of oolithe grains is optimal.
- Attrition time is prolonged by recycling of the oversize fraction +2,5mm to the mill, i.e.closed circuit grinding.
- Wet attrition by a special attrition cell could be shortened to minimum.
- In the material -2,5mm there will be practically no broken oolithes.
- A PERIMILL will ensure the same liberation conditions for oolithes indurées, oolithes tendres and intercalation, regardless of Fe-content, i.e.cut-off 35 %Fe, taking into account that intercalation consists of iron oolithes bigger than 0,50mm in clayay-sandy matrix.
- No selective mining will be necessary!!

## 2.3 Desliming.

Contractor has deslimed fraction -0,50mm for HIWMS purposes on ±0,020mm.

Meanwhile screen analyses of the fraction -0,50mm have showed that desliming on ±0,10mm*) will give practically the same or even better technological results: See Annex C-13!

| Fraction | | %W | %Fe | %R | $\%SiO_2$ | %R |
|---|---|---|---|---|---|---|
| -0,50 ÷ 0,30 | mm | 11,2 | 34,1 | 9,2 | 27,9 | 17,1 |
| -0,30 ÷ 0,10 | mm | 11,o | 22,2 | 5,9 | 41,1 | 25,1 |
| -0,10 ÷ 0,063 | mm | 2,4 | 16,5 | 1,o | 45,7 !! | 6,1 |
| -0,063 | mm | 2,3 | 18,1 | 1,o | 34,9 !! | 4,5 |

These results are based on a material which was crushed by force by a hammer mill, i.e.the crushing which gives a considerable quantity of crushed oolithes in the fraction -0,50mm. Meanwhile FERIMILL will give practically no broken oolithes!!

*) or even 0,15o mm!!

## 2.4 Attrition.

Attrition is a very important process phase. By attrition

- clayay matrix between oolithes should be separated and
- clayay oolithe-surface shells should be abraded, taking into account that each oolithe has a barren shell of some tenth microns thickness which seems to be of the same hardness as oolithes themselves.
- Attrition of the soft clayay matrix represents no problem, meanwhile attrition of the oolithe shells demands more time and optimal attrition conditions, the conditions which occur only during autogenous grinding.

Conditions of attrition of the fraction -3mm were probably not optimal, concerning the pulp density:

| | g/dm$^3$ | dm$^3$ solid | dm$^3$ water | Ratio s/w |
|---|---|---|---|---|
| Sample 1 | 1100 | 0,415 | 0,585 | 65/35 |
| Sample 2 | 1300 | 0,490 | 0,510 | 72/28 |

Taking into account relatively low spec.density of the oolithes - with a bulk density of 1,92 - attrition conditions were acceptable for sample 2, but not for sample 1.

Attrition is namely successful when ratio s/w is about 70/30 to 75/25, depending upon the volume concentration.

2.5 HIWMS.

The only successful process for the beneficiation of deslimed fraction -0,50mm is HI Wet Magnetic Separation.

Oolithic ore crushed by a hammer mill has always a higher percentage of broken oolithes in the fraction -0,5mm.
But oolithic ore milled by a PERIMILL contains practically no broken oolithes.

The fraction-0,10mm is practically pure matrix material, i.e. clayay material which should be deslimed without any deterioration of Fe recovery.
In this case HIWMS will operate under much better conditions!

Dewatering of of any concentrate +0,10mm represents no problem.

Fraction for HIWMS.

All beneficiation tests have been elaborated on the basis of two main fractions:
/-3 + 0,5/mm and fraction -0,50mm.

Taking into account data - se page B 16 ! - that quartz grains are mainly in the fraction -0,63mm, I recommend the following fractions:

- fraction /-2,5 + 0,6/mm and
- fraction -0,60mm, the fraction which should be deslimed on ±0,10mm.

Material /-0,6 + 0,1/mm is still a very convenient one for HUMBOLDT JONES HIWMS process.

3. Conception for the exploitation of the iron ore deposits.

All critical remarks about C.6.1 - Treatability of the differend ore horizons - are correct taking into account the proposed beneficiation scheme, i.e.crushing by a hammer mill.

By an autogenous mill with peripheral discharge, desintegration of oolithes will be optimal,
- practically without broken oolithes in the fraction +0,6mm,
- without broken oolithe particles in the fraction -0,60mm
- and with an attrition under optimal conditions.

Evenmore, by introducing a PERIMILL close circuit grinding, the beneficiation conditions of all iron ore horizons, including intercalation, will be equaled, regardless of the Fe-content.

No selective exploitation will be necessary and all three iron ore horizons could be exploited at once.

The quantity of the fraction -0,60mm will be strongly increased:
- partly due to the decreasing of upper size from 3 to 2,5mm,
- partly due to the screen size increasing from 0,5 to 0,6mm and
- mainly due to a strong attrition action during the autogenous milling in closed circuit by a PERIMILL.

By first desliming on ±0,10mm, attrition conditions will be strongly improved.

According to these scheme improvements the following concentrate could be produced:

| | | | |
|---|---|---|---|
| Fe concentrate | with 53...55 %Fe, | in ignited state | 62±1 %Fe |
| with approx. | 2 % $P_2O_5$ | " | 2,3 % $P_2O_5$ |
| with approx. | less than 4 % $SiO_2$ | " | 4,5 % $SiO_2$ |

Such a concentrate could be a very good raw material for local consumption - Niger and north Nigeria -but due to low basicity and mine remote location, any export possibilities are excluded, taking into account that river Niger is not navigable between Niamey and the river mouth.

## 4. Pelletizing and Direct Reduction process.

I have no remarks on the pelletizing tests.
Contractor has proved that high quality acid pellets could be produced.
Pellets with a basicity 0,8 could not be produced.

Meanwhile the problem of pelletizing should be treated in connection with the chosen reduction process.
Among the many DR processes, contractor has chosen and recommended KR process, the process which has many advantages, although untill now - August 1984 - no industrial KR plant has been put in operation.

But for the chosen KR process pelletizing is not at all necessary. KORF Engineering claimed that by KR process the following iron ores could be used:
- pellets,
- natural pellets -25mm and
- sinter !!

In our case the concentrate /-2,5 +0,1/mm represents an exellent sinter material and even self-fluxing sinter is not excluded.

Therefore there is no need for the following proposed expensive phases:

- fine grinding of Fe concentrate and
- pelletizing of such a ground Fe concentrate.

The proposed metallurgical KR process - which produces pig iron - enables use of Fe concentrates with over 0,20 %P, taking into account that a dephosphorization process should be provided in the steel plant.

## 5. Conclusions and proposed scheme.

### 5.1 Exploitation of iron ore deposits.

Oolithic iron ore will be exploited by riping. A CAT D8H with one-teeth hydraulic riper will be probably sufficient strong, since oolithic ore is strongly bedded.
Ore produced by riping has practically no boulders!

### 5.2 Crushing.

Ore should be crushed by a primary single-toggle crusher 1000 x 800mm.
Recommended discharge setting 250mm.
Crushed ore will be stocked on a small open pile.

### 5.3 Grinding.

Crushed ore -250mm is a feed for an autogenous KRUPP PERIMILL, with peripheral openings 5mm, probably without grinding balls.

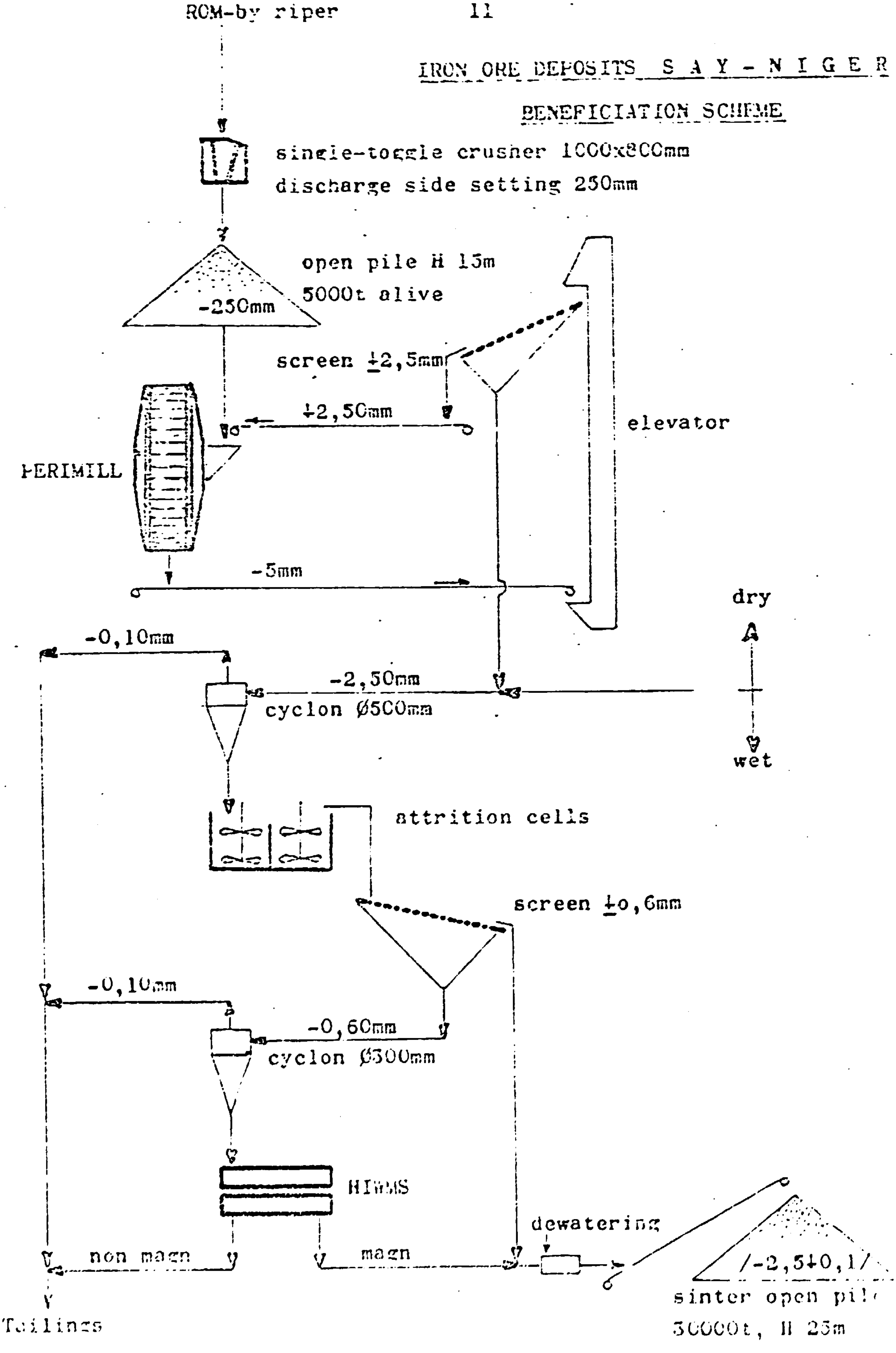
The mill will work in closed circuit with a screen +2,50mm.
Oversize +2,5mm will return to the mill.

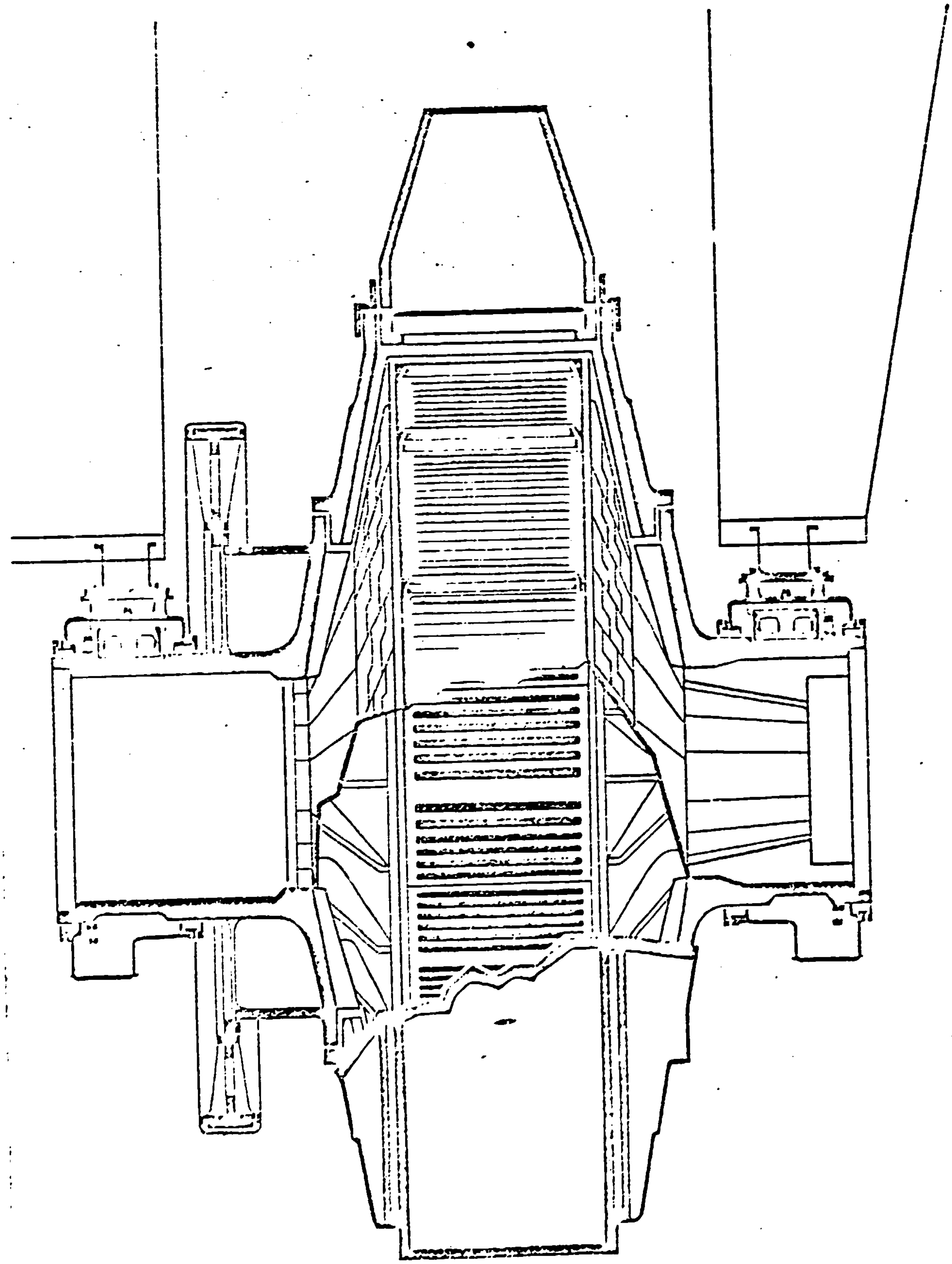
### 5.4 Desliming.

Undersize material -2,50mm should be deslimed in front of attrition by cyclons: Ø about 500mm, pressure about 0,5 bar.

IRON ORE DEPOSITS S A Y - N I G E R

BENEFICIATION SCHEME





5.5 Attrition of material /-2,5 + 0,1/mm.

Attrition time by an attrition double blade cell will be maximum about 5 min.

5.6 Screening on +0,6mm.

Oversize +0,60mm will be dewatered.
Undersize /-0,6 + 0,1/mm is feed for HIWMS.

5.7 Desliming of fraction -0,60mm.

Fraction -060mm should be deslimed in front of HIWMS.

5.8 HIWMS.

Fraction -0,60mm will be separated by HIWMS and concentrate will be dewatered together with the concentrate +0,60mm.

5.9 Sintering.

Limestone or dolomitised limestone will be added to the Fe concentrate and a self-fluxing sinter will be obtained.

5.10 KR process.

KR process produces a pig iron with phosphorus.
A dephosphorization process - LDAC - in the steel plant will produces Thomas slag - a fertilizer - for local consumption.

5.11 Slag.

Due to high $Al_2O_3$ content in Fe concentrate, a specific slag with high alumina will be produced with the following analyses:

| | | | | | |
|---|---|---|---|---|---|
| $SiO_2$ | about | 34±4 % | $Al_2O_3$ | about | 18 ±2 % !! |
| CaO | about | 38±3 % | MgO | about | 6 ±1 % |

Such a slag - with high alumina content - is today produced

only by some iron work plants like:
- Appleby Frodingham, Great Britain,
- Iron Works Skopje, Yugoslavia and
- some Australian iron works.

Appleby Frodigham is selling this slag
- partly as CALUMITE for glass industry and
- partly is grinding this slag and the product is a valuable cement, marketed as CEMSAVE.
  By adding 20...30% hydrated lime, this cement is used for the construction of water dams.

6. Remark.

Krupp Industrie and Stahlbau, Rheinhausen, FRG, dispose of a pilot plant with a PERIMILL Ø1,9m x 0,9m, which is working in closed circuit with a screen ±2 mm.

Designing of the mill demands in any case a pilot plant grinding test, the test which will prove that a PERIMILL is an ideal device for desintegration of soft oolithic ore,
- without crushing the oolithes and
- that optimal results concerning quality and Fe recovery could be obtained by an autogenous grinding.

Ljubljana, 18th August 1984

Viktor Košir

KHD HUMBOLDT WEDAG AG

Comments and Answers to Questions of Participants at the Final Meeting at Niamey on November 6th to 9th, 1984

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Question 1: from UNIDC, Vienna

Your opinions from both technological and economical viewpoints on the introduction of an autogenous mill, KRUPP PERIMILL, within the ore processing line, which UNIDO expert is proposing.

Answer

We feel that autogenous mills will be unsuitable for processing the ore from Say because the oolithic material is very brittle and cannot be used as grinding media.

For avoiding large portions of superfine material, i.e. for minimizing the destruction of ooliths, an impact mill with positive discharge mechanism will likewise be appropriate. Iron-ore mines in the Southern part of Germany have gained satisfactory experience with this equipment.

In an impact mill, the amount of superfine material can be controlled via the cirumferential rotor speed. Another option for heedful comminution of the material will be the use of a rod mill or - with restrictions - of a roll mill. Manufacture of the Krupp "Perimill" was discontinued some time ago.
It is assumed that a rod mill will be installed in a large-scale plant.

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Question 2: from UNIDO, Vienna

Advantages and disadvantages of the adoption of a sintering process instead of a pelletising plant, in connection with the Niger ores, assuming that KR Smelting process can be applied and sintered ores can be used for this process

Answer

Disadvantages of the application of Sintering process

- It is fundamentally possible to produce the so-called "MONOSINTER" using the iron ore concentrate of Niger having the chemical composition:

| | |
|---|---|
| Fe | 5o % |
| $SiO_2$ | 7 % |
| $Al_2O_3$ | 4 % |
| CaO+MgO | o,2 % |

  On the basis of the high amount of acidic components $SiO_2$ and $Al_2O_3$ and a lack of sufficient amount of basic ingredients like CaO and MgO in the ore concentrate, it is only possible to produce an acid sinter.

  The production of basic or self-fluxing sinter is only possible through an addition of sufficiently, and in this particular case uneconomically high contents of limestone or dolomite to the sinter mixture. The acid sinter is known to have bad reduction characteristics because of the formation of iron silicates during the sintering process. In this case the iron content will be bound as FeO to form fayalites. For this reason it is not possible to achieve high oxidation degrees of sinter.

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- As mentioned above it is necessary to add limestone or dolomite to the sinter mixture to produce a well reducible sinter using the Niger iron ore concentrate. The limestone or dolomite have to be of good steel works quality and to contain less gangue elements. Such resources are not available in the vicinity of the iron ore deposit of Say and must be imported from external sources over long distances. This makes sinter production uneconomical.

- The extraneous addition of substances like limestone or dolomite to correct the chemical composition of the sinter reduces the iron content further more and increases the slag content while smelting which leads to a high energy consumption.

- The sintering process needs an energy source in the form of coke breeze or semi coke having a grain size of o to 6 mm.

  The coke breeze is an unavoidable by-product of the coke ovens while producing metallurgical coke.

  Because of divers other reasons, sinter plants are normally integrated with large steel works and the coke breeze is available as a by-product free of additional cost. If the sinter plant is built elsewhere, e.g. coupled with a mini-mill, the coke breeze must either be produced additionally for sintering purposes or must be purchased from external sources (as e.g. from coke oven composite plants of Ruhr area in Germany). The purchased coke breeze is expensive (price about 1oo $ per ton including overheads). Our knowledge of the coal deposits in Niger and the coking characteristics of such a coal is very limited to make any comments on this aspect.

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- As regards to environmental pollution, sinter plants are much disadvantageous in comparison to pellet plants. The dust and sulfur emissions of a sinter plant are admost the double of that of a pellet plant. Sinter plants also emit hazardous $NO_x$ which forms when hot air passes through the sinter layer at high temperatures. The removal of $SO_2$ and $NO_X$ from the sinter flue gas with the help of modern desulphurising and de-$NO_X$ plants is very expensive and makes the whole process uneconomical.

Advantages of the application of sintering process

According to our opinion, the only advantage by applying the sintering process is the energy saving for the fine grinding stage which is a necessary factor for the pelletising process, for pelletising the iron ore concentrate must be finely ground to a Blaine-value of 18oo - 2ooo $cm^2$ per g. which is a very energy-intensive step. The sinter process needs more coarser grains of iron ore, o - 6 mm, for better gas permeability during sintering.

Question 3: from UNIDO, Vienna

Any metallurgical or any other comprehensive explanations against the facts that the solids reduction tests have obsolete results with regard to the metallisation, on the other hand, REAS-test simulating KR-smelting process has given good results.

Answer

To achieve a high degree of metallisation during the reduction of iron ore with solid carbon, the coal or coke breeze used in the process must fulfil the following prerequisite;

The coal or coke breeze used must be of a good quality and contain less ash and sulfur contents. The high ash contents of the coal, as we presumed to be the case in Niger, hinder the reduction of the iron oxides. The ingredients of the coal ash, expecially $SiO_2$, react during reduction with iron oxides to form low melting Eutectika like iron silicates, which are difficult for reduction. This is the main reason why we achieved such low degrees of metallisation in own laboratory trials.

The coal sample from the Philippines (SEMIRARA coal), which was used in our laboratory trials, is assumed to be similar in mineralogy and chemical composition, especially the high ash content, to that of Niger coal.

If other high quality coal is available for the reduction process, we are sure that it is possible to achieve higher degrees of metallisation.

The above mentioned disadvantage of solid reduction while using poor quality coal does not appear while conducting the REAS-test. In this case the iron ore pellets are reducted at first to 9o % degree of reduction at 9oo °C using a gaseous reduction agent having 7o % CO, 25 % $H_2$ and 5 % $N_2$. This type of reducing gas is generated in an industrial KR-plant by gasifying coal with oxygen in a smelting gasifier. The coal ash which will be separated and removed as liquid slag from the smelting gasifier does not come into contact with the iron ore during the whole reduction process.

Because of the reasons mentioned above we did not consider the SL-RN* direct reduction process as one of the alternatives to be employed in the State of Niger. The SL-RN-process uses solid carbon in the form of coal, coke breeze or semicoke in a rotary kiln as a reducing agent and this is intermixed with the iron ore.

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* SL-RN = Stelco-Lurgi - Republic Steel - National Lead

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Question 4: from UNIDO, Vienna

Any information on the existing works / plants in the world where the same type of ores (oolithes indurees, oolithes tendres) as in Niger are being used to produce steel

Answer

In the area of Elsaß-Lothringen, West-Europe, a lean iron ore deposite called the "MINETTE" is used as a raw material for iron production. Its mineralogical character and the chemical analysis of the MINETTE are very similar to that of the iron ore deposits of Niger as far as the low iron and high phosporous contents are concerned.
The main difference lies in the availability of the high contents of $CaCO_3$ in the MINETTE. This characterises MINETTE as a basic ore, which means that no limestone additions are needed while sintering.

MINETTE is used as a raw material in all steel works of the Elsaß-Lothringen region, especially in the ARBED* -works of Luxemburg. The MINETTE sinter is charged into the blast furnace to produce a phosphorous rich pig iron. This is subsequently converted to low-phosphorous steel by using the LD-AC-process**.

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* ARBED — Aciérie Réunies de Burbach-Eich-Dudelange S.A.
19, Avenue de la Liberté, Luxembourg
Works in Dudelange , Esch-Schifflange, Esch-Belval and in Differdange

** LD-AC-Process — Linz-Donawitz-Arbed-CNRM-Process

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Question 5: submitted by A.C. Lukoya, Kaduna / Nigeria

Did the broad classification of the oolithic ores take note of the modality of deposition, grain distribution and degree of sorting established by use of the scanner electronical microscope ?

Answer

Sub-dividing the iron-ore horizon into
- an upper horizon of Oolithes Indurées
- an Intercalation of sand and clay of low contents of iron ooliths, and into
- a lower horizon of Oolithes Tendres

is based on geological and mineralogical observations derived from outcrops, pitting and trenching and drill cores.

The classification established in this manner has been substantiated by the results of chemical analyzing and by mineralogical characteristics.

According to the statements made in chapter B 6, the conditions prevailing during deposit formation of the three horizons varied which means that the classification has also been based on genetic aspects. This classification is applicable to all parts of the deposit.

Similarly, it is applicable and has been chosen for selective working of the deposit and the specific processing methods.

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Question 6: submitted by A.O. Lukoya, Kaduna / Nigeria

Has nothing but goethite been evidenced as iron-bearing mineral by means of microscopic examination and SEM (scanner electronical microscope), although this sedimentary type of ore could be expected to include also other iron-bearing minerals, such as hematite, siderite, etc. ?

Answer

As detailed in chapter C 4.1.1.1 and C 4.1.1.2, examining under a microscope and a scanner electronical microscope (SEM) revealed but the iron-bearing minerals goethite ($\alpha$-FeO · OH) and lepidocrocite ($\gamma$- FeO · OH), and very rare hematite. No other iron-bearing minerals, such as magnetite, siderite or pyrite have been determined. Considering the genetic conditions ot the iron ooliths, the iron-bearing minerals mentioned above are actually not expected to occur associated with goethite ooliths.

Question 7: submitted by A.O. Lukoya, Kaduna / Nigeria

In what form and distribution does alumina occur, in particular in the ooliths and in the matrix ? Are there ways and means to reduce the Al content by attrition and classification as the Al concentration will affect slag formation during smelting ?

Answer

Paras B 4.1, page B 18 and C 4.1.1.1 and C 4.1.1.2, page C 8 and following, explained that aluminium has been located primarily in the matrix as kaolinite between the ooliths.

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Moreover, Al occured very finely distributed in the ooids, bonded adsorptively to goethite (see figs C 9 and C 10). The $Al_2O_3$ content in the ooliths has been of an order of magnitude of 3.3 %.

The average $Al_2O_3$ content of the ores (see pages B 19 to 21) has been as follows:

| | |
|---|---|
| in the Oolithes Indurées | between 4.34 and 4.64 % |
| in the Intercalation | between 5.83 and 8.21 % |
| in the Oolithes Tendres | between 5.89 and 7.33 %. |

The $Al_2O_3$ content can be noticeably lowered by way of processing, i.e. by comminution and classification (see para C 4.23, page C.24 and C 5.2.1, page C.34) thereby reducing the kaolinite content of the matrix.

In the course of the dressing tests carried out for concentrate production, the $Al_2O_3$ content could be lowered to the following levels:

| | | |
|---|---|---|
| for Oolithes Indurées | by about 52 % | and |
| for Oolithes Tendres | by 42 %. | |

Hence, it has been reduced to approximately half the original value (see analytical data given on pages C 19 and C 40).

As expected, treating the ground ROM ore in a magnetic separator entailed but a minor reduction of the $Al_2O_3$ content because kaolinite has been relatively concentrated in the fraction minus o.5 mm.

Reducing the Al content that is adsorptively bonded to goethite in the ooliths by way of magnetic separation will be impossible because this would necessitate grinding to less than micron size.

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It is a well-known fact that the $Al_2O_3$ content of the ore is among the acid components. This means that the higher the $Al_2O_3$ content, the more basic additives, such as limestone, have to be added so as to establish a slag basicity of approx. 1 ( ratio $\frac{CaO + MgO}{SiO_2+Al_2O_3}$ ) which is required for proper blast-furnace operation.

A slag of this type features advantageous smelting and flow properties at typical blast-furnace temperatures. Blast-furnace experts request the ore feed to have a $SiO_2$ : $Al_2O_3$ ratio of about 3 : 1. This will minimize the accumulating slag quantity to the necessary level and at the same time keep the coke consumption rate per t of pig iron within acceptable limits.

Question 8: submitted by A.O. Lukoya, Kaduna / Nigeria

This question is based on the assumption that a technico-economical study had included pilot tests at least of very preliminary kind as it would be of advantage to perform a coke rate analysis for quality assessment of the ores.

Nevertheless it should be possible to calculate the coke rate values for smelting the iron ores from Say by the suggested methods either on the basis of theoretical calculations or of mathematical blast-furnace models. This would facilitate understanding the problems associated with bonding of phosphorus in the slag.

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Answer

The present project was a preliminary study of the iron ore deposits and did not provide for pilot tests of several days in a KR plant in Germany because tests of that type involve considerable expenditure.
These tests should of course be part of a technico-economical study still to be performed.

However, theoretical and practice-related empirical values regarding the coke consumption rate per t of pig iron are available from a KR plant. These figures are valid only on the bases of given premises, such as composition of the ore to be molten and composition of the coal. The data at our disposal as to composition and coking properties of the coal available in the Republic of Niger are inadequate for making statements in this respect.

According to the results obtained for the KR process in the past, the consumption rates are approx. 1 t of coal / t of pig iron. However, this figure substantially depends on the contents of $C_{fix}$ and of ash in the coal used.

The distribution of P in metal / slag as a function of the coke consumption in the KR furnace is irrelevant for the investigations made here because the P content of the ore is almost completely transferred to the pig iron during smelting in the KR furnace in a reducing atmosphere and because dephosphorizing of the pig iron occurs outside the KR furnace in the steel converter.

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Question 9: submitted by A.O. Lukoya, Kaduna / Nigeria

What have been the reasons for selecting the specific binders for the pelletizing tests, e.g. charcoal from Brazil and coal from Indonesia ?
The energy raw materials available in Niger have not been investigated. According to my opinion this should have been part of a techno - economical study.

Answer

Adding 1 % of charcoal during pelletizing test NEP 6 has been done for other reasons than to serve as binder. The actual function of a binder, as e.g. bentonite, is to increase capillary forces during green pelletizing thereby improving the strength of green pellets. Coal as such does not have bonding properties. Adding charcoal was only meant as additional energy carrier for green pellets baking. This will substitute part of the expensive fossil energy such as natural gas or mineral oil (which are missing in Niger) by less expensive coal.

Coal originating from the Philippines having a chemical composition that is similar to that of the coal available in the Republic of Niger, has not been used as binder but as reduction agent upon pellet reduction in the rotary drum for ascertaining their decomposition and metallization characteristics. These tests were necessary for finding out whether the pellets made of Niger ore were suitable for the KR process.

Examining the energy raw materials occurring in the Republic of Niger was out of the scope of the "Preliminary Study" all the more as these materials had not even been primarily tested by the pertinent national organizations.

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The energy raw materials locally available will have to be investigated under a further techno-economical study regarding the use of iron ores from Say.

<u>Question 10</u>: submitted by A.O. Lukoya, Kaduna / Nigeria

What considerations and investigations have been made as to profitable production of 100,000 t of steel in the Republic of Niger taking into account the limitations inherent in the KR process ?

<u>Answer</u>

It is a well-known fact that profitability of a plant is substantially influenced by the "scale-up" factor. The larger the production capacity of a plant, the lower will be the production cost / unit. The bottom limit value for profitable production in a KR plant ranges at approx. 100,000 t of pig iron / year for each plant module. According to the present state of the art KR plants reaching capacities up to 300,000 t of pig iron / year and plant module can be built.

On the basis of published data and market investigations carried out by us for the Republic of Niger and its neighbouring countries, the current demand for various steel products within that area equals about 100,000 t / year at a maximum.

<u>Question 11</u>: submitted by Mr. Biry, ONAREM, Niamey, Republic of Niger

Mr. Biry pointed out that according to the publication by J. Greigert, entitled: "Description des Formations Crétacées et Tertiaires du Bassin des Iullemeden - Edition du BRGM, Paris 1966", the "Birrimien" has to be classed in the Middle

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Precambrian and that, according to J. Greigert, the "Volta Sandstone" corresponds to the Infracambrian or the Eocambrian.

Answer

The description of the stratigraphic sequence given in chapter B 3 is a general survey of the geologic history within the examined area. In compliance with the specific task, emphasis has been laid on the younger strata (Tertiary and Quaternary) of the stratigraphic sequence which, moreover, include the oolithic iron ore deposits. Therefore, no stratigraphically closer gradation has been provided for the rocks of the basement, i.e. metamorphites and granites of the "Birrimien" nor of the rocks identified as "Volta Sandstone".

It is correct that upon a stratigraphically narrower classification, the formation of the "Birrimien" has to be included in the Middle Precambrian.

As to the stratigraphic classification of the "Volta Sandstone", i.e. a series of clastic sediments in the Volta Bassin which occur discordantly on folded and metamorphic "Birrimien", M. DEYNOUX et al. (1978) have specified the following classification and age determination:

- sandstone and schists of the Dapango-Bombouaka Group ( 993 $\pm$ 62 million years )
- greenish flyschoid sequences and graywackes with isolated occurence of stromatolites and sponges of the Pendjari and/or the Oti Group ( 660 $\pm$ 8 million years to 615 million years )

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- reddish sandstones of the Obosum Group ( younger than 613 ± 9 million years )

These clastic anchi- to epimetamorphic rock sequences have by us simply been combined to "Volta Sandstone" and classified as belonging to the Eocambrian because large portions are within the Early Precambrian which has been confirmed by the age determination.

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