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BENEFICIATION OF ESHIDIYA LOW GRADE ROCK

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RESUME

La mine d'Eshidiya est située au sud de la Jordanie à environ 125 km au nord-est du port d'Aqaba et elle est appelée à devenir la principale zone de production minière en Jordanie avec un total de réserves de 2 milliards de t. Le gisement de phosphate à la mine d'Eshidiya se présente en couches continues, 90 % environ du minerai de phosphate venant d'une zone couverte par Coquina (zone Coquina), le reste de la zone non Coquina. Chacune des deux zones mentionnées a certaines caractéristiques, la zone Coquina se caractérisant par l'existence de carbonates dans les fractions dures et friables, la teneur en argile étant faible et la teneur en chlore étant considérée comme faible. En ce qui concerne la zone non Coquina, le minerai se caractérise par plus de minéraux argileux associés aux oxydes de fer et parfois enrobés de particules de quartz.

En général, les couches de phosphates à bas titre d'Eshidiya sont décrites de la façon suivante :

- *Couche phosphatée A1 de minerai pauvre 45-50 % BPL sera enrichie pour produire un concentré de titre moyen (68-70 % BPL) par lavage et deschlammage pour séparer les fractions grossières et très fines.*
- *Couche phosphatée A3 (bas titre) 30-50 BPL est enrichie pour produire un concentré à haut titre (75/77 % BPL) par lavage suivi de flottation.*

Dans cette communication, on examinera en détail comment les couches A1 et A3 de phosphate d'Eshidiya sont enrichies pour produire un phosphate à haut titre et son évaluation dans la production d'acide phosphorique et d'engrais phosphatés.

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JORDAN PHOSPHATE MINES CO., LTD. (JPMC)

JPMC was established as a private company in 1935 to exploit phosphate deposits in Ruseifa 12 km north east of Amman. In 1953, it became a public share holding company. The company started production in 1963 from Al-Hassa mine, located 136 km south of Amman, and 200 km north of Aqaba port. Production from Al-Abiad mine started in 1979 which is located about 20 km north of Al-Hassa mine. In 1988 the production started from Eshidiya mine which is located about 125 km south east of Aqaba. The production capacity of the three mines is about 8.5 MTPY from various grades.

In 1982, a fertilizer complex was constructed about 17 km south of Aqaba to produce phosphoric acid, diammonium phosphate (DAP) and aluminum fluoride. In early nineties JPMC decided to rehabilitate the phosphoric acid plant in order to upgrade its annual production capacity, product quality and yield. The rehabilitation was completed at the end of 1993 with a resulting capacity of 432,000 MTPY of P_2O_5 and 800,000 MTPY of DAP.

Expansion and new cooperation schemes are currently underway to maximize utilization of Jordan's resources, and since producers can no longer depend simply on the production of raw materials for continuity, JPMC adopted a new planning policy embodied by the contribution in several recent International joint ventures, as follows:

1. Nippon Jordan Fertilizer Company - NJFC

NJFC Company is a joint venture scheme with four Japanese companies, JPMC and APC to build a 300,000 t/y NPK fertilizer and di-ammonium phosphate (DAP), output from this plant will be sold to Japan. Production is scheduled in April 1997.

2. The Indo-Jordan Plant Chemical Company

The Indo-Jordan Chemicals Company is a joint venture between JPMC, Southern Petrochemical Industries Corporation (SPIC) of India and the Arab Investment Company - Saudi Arabia.

This plant located at Eshidiya will produce 225,000 tons of phosphoric acid. The product will be exported totally to India.

3. FFC - Jordan Fertilizer Co - Pakistan

This project is a joint venture between JPMC and Fauji Fertilizer Company Limited (FFC) to produce DAP, urea and ammonia.

This plant is located at port Bin Qasim, where JPMC will supply this project with 210,000 TPY of phosphoric acid.

In conclusion the fertilizer industry in Jordan is being developed in accordance with the long-term plans set - up to secure a rational exploration of the country's available natural resources. The development strategies have been elaborated with due consideration, given to the present world market situation and future outlook.

The large reserves of phosphate deposits together with Jordan's geographical location, the experience gained during forty years of operation and marketing of fertilizer commodities to more than 30 countries in the world have provided the foundation of which Jordan's development strategies are based.

Apart from its own national interests, Jordan is achieving its role in meeting world fertilizer needs for decades to come by developing its fertilizer industry.

The above ambitious plan in the phosphate fertilizer development requires extensive development of phosphate industry in Jordan.

In this paper we shall talk about beneficiation of Eshidiya phosphate in order to fulfill the requirement of JPMC market local and abroad.

BENEFICIATION OF ESHIDIYA LOW GRADE ROCK

1. Eshidiya Mine

Eshidiya is located at the south of Jordan, about 50 km south-east of the city of Ma'an and about 125 km north-east of Aqaba.

JPMC future strategy will concentrate on the progressive development of Eshidiya deposits, in addition to the two other mines El-Hassa and El-Abiad in the south of Jordan. The production capacity of Eshidiya mine will be gradually increased to reach 10 million MTPY by the turn of this century.

Detailed drilling and geostatistical studies identified an ore reserves in excess of 2 billion tons of phosphate and expected to increase on - going explorations.

The Eshidiya deposit is characterized by two distinct zones, the western and eastern ore bodies. Studies revealed the presence of certain lithological and mineralogical properties due to the presence or absence of the coquina limestone. Thus the ore body was classified into two areas the coquina and non-coquina area .

Coquina area is distinguished by the presence of a relatively thick overburden in which phosphatic layers (A_0) lies on top of coquina, followed by the sequence of 3 phosphatic layers separated by interwaste rock. The characteristics of the ore lies in its high CaO/P_2O_5 ratio and its lower chlorine and R_2O_3 values .

The presence of coquina layer dictates certain selective mining techniques for the removal of overburden and phosphatic layers, from the beneficiation view the phosphate layers treatment is much simpler specifically for A1, A2 layers .

During the recent years the minimum ore-grade limits have decreased from about 20% to less than 10% P_2O_5. However, this represents the preferred textures of concentrates for acidulation processes i.e. soft, porous, phosphate particles. In this paper, we will concentrate on the beneficiation and characterization of the non-coquina area .

The phosphate deposits at Eshidiya mine occur in continuous beds. The phosphatic layers are described vertically from top to bottom as follows:

- Phosphatic Layer A1, to produce concentrate grade of 68/70% BPL.
- Phosphatic Layer A2, to produce concentrate grade of 73/75% BPL.
- Phosphatic Layer A3, to produce concentrate grade of 75/77% BPL.

2. Mining and Exploitation

Mining and exploitation of phosphate rock in all operating mines is carried out through a mechanized open cast mining technique using electric walking draglines. The uncovered phosphate is usually loosened by ripping, drilling and blasting and then loaded into dump trucks for hauling to crushing and screening plants.

3. Characteristics of the Ores

The phosphate layers A1 and A3 are made up of soft fractions usually rich in phosphate associated with variable contents of minerals such as quartz, clay and calcite.

It was found that the chemical composition of the phosphatic layers varies according to the layer considered and generally the TCP content of A1 ore ranging between 46-50% TCP and A3 ore 35-40% TCP.

4. Beneficiation

Laboratory and pilot plant tests were carried out on many samples, collected from the pits over the selected mining area, 60% of that area is located under the coquina, and the rest 40% is located under the non-coquina.

After pre-treatment to withdraw coarse rejects, most of the ores are wet beneficiated, this includes ore washing followed in most cases by flotation to increase the %TCP.

Thus the main beneficiation stages considered at the industrial stage for the wet treatment of the ores are as follows:

4.1. Washing Processing

For A1 from the coquina and non-coquina areas, by pulping, scrubbing, attritioning and several desliming stages carried out on the screened -12 mm fraction, concentrate grades ranging from 68-70 % TCP are obtained in the fraction - 1 + 0.05 mm for A1 from coquina area, and in the fraction - 1 + 0.5 mm for A1 from the non-coquina area are subjected to flotation.

4.2. Flotation

Phosphatic ores A1 (Fine fraction - 0.5 + 0.05 mm) from the non-coquina area and A3 ores from both coquina and non-coquina area (fraction - 1 mm + 0.05 mm) show favourable tendency for silica phosphate separation by flotation.

NON-COQUINA ORES IN ESHIDIYA MINE

Non-Coquina Area

In the non coquina area, the disappearance of coquina towards the southeast has been caused by lateral facies change of limestone towards marly facies. In this area the same 4 phosphatic layers are existing and characterized by lower CaO/P_2O_5 ratio, higher chlorine and R_2O_3 values. In this zone all phosphatic layers and possibly interwastes could be mined as « whole section » and it would also result in a more sophisticated beneficiation treatment.

Characteristics of the non-Coquina Ore

Phosphate rocks originating from this area have lower percentage of hard fractions, however, phosphatic layers have lower TCP content due to higher proportions of impurities present as associated mineral (clayey silicates, quartz chert, phosphatic chert).

By separating the coarse fraction (medium hard / hard) no significant upgrading occurs.

Phosphate bearing particles have the highest P_2O_5 content (38.73%), such high phosphate particles enable to obtain high grade (80% TCP) by conventional benefication.

The following are the basic characteristics of this type of ore:

1. Lower CaO content (CaO/P_2O_5) when compared with coquina area due to the nearly absence of free carbonate matrix in phosphatic layers. In addition to the lower CaO/P_2O_5 ratio in the bearing particles.

2. Silica Content

   Silica content which is present as abundant red, yellow clays free detrital quartz forming associated minerals in phosphatic layers.

3. Chlorine & Al_2O_3 (R_2O_3)

   All phosphatic layers have much higher values mainly originating from red or yellow clays.

As it is shown by the chemical analysis of pits samples located within the south east area of the western Eshidiya deposit, the iron and aluminum oxide accounting for higher clay minerals and hydroxides. Most of this iron clay occur as a cement filling the pores and voids of phosphoranite and as a coating at the surface of phosphate particles. Therefore thorough cleaning of the particles surface will be required before conditioning and flotation.

The chemical composition of phosphate particles are shown in Table 1.

Mining

The same phosphatic series are existing in this area, it is found that chemical & mineralogical characteristics are gradually changing when approaching from coquina towards non-coquina area, whereas a transition zone (boundary line areas) has similar characteristics of both coquina & non-coquina.

The non-coquina area has the following parameters:

a. Overburden

The thickness of the overburden decreases reaching an average of 6-7 m. Hard intercalations in marl layer are not existing as that of coquina area, which results in reducing consumption of explosives.

b. Phosphatic series

The thickness of phosphatic series is generally similar to that in coquina area. As for the associated hard intercalations (interwastes) the thickness decreases. In summary the stripping ratio decreases sharply. 1:1 stripping ratio is frequently encountered.

Phosphatic Bed A1

Contrary to coquina area, all sublevels (B+C+D+E) are characterized by much lower CaO/P_2O_5 ratio in addition to higher clayey silicates, quartz content.

Therefore, mining of A1 layer as a whole will be carried out.

Phosphatic Bed A2

This layer has lower phosphate grade due to the presence of high percentage of impurities (clay, silica) which excludes the dry processing of the layer.

Phosphatic Bed A3

A3 layer is present in facies type 2, mainly occur as soft phosphate.

Mining of this layer is of economical interest.

Interwaste

The interwastes material IW1, IW2 have lower thickness (1.0 m combined thickness) and associated with soft phosphate material. Since the beneficiation route will be the same for the phosphatic beds A1, A2, A3. It becomes essential to consider a whole section mining including the interwaste materials as one unit.

As for the beneficiation of low carbonate phosphate, the following factors appear to effect concentrability:

a. Amount of clay matrix

Phosphate from this area usually contains a high amount of clay cement associated with iron hydroxides so it requires a high energy attritioning in order to yield clean fractions (- 1 + 0.05 mm) with acceptable residual aluminum and iron contents.

b. Friability of phosphate particles

Eshidiya phosphate rock is friable and due to handing the reactive surface becomes high variations in the collector consumption and recovery of coarse sized phosphate might be attributed to the amount of phosphate slime generated in conditioning and flotation phosphate slimes with a high surface activity adsorb the collector which results in increased collector requirements.

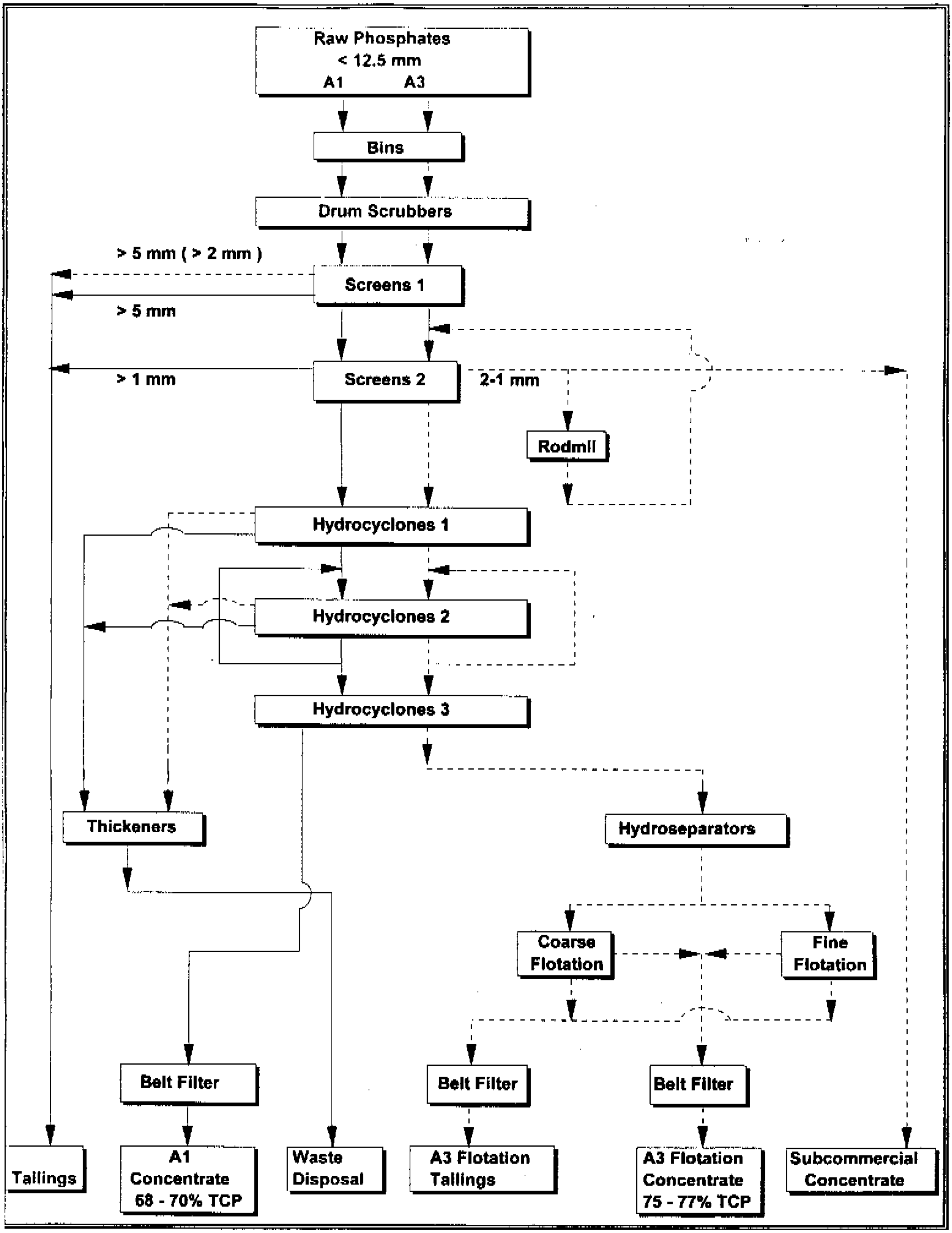

Raw Phosphates
< 12.5 mm
A1
A3
Bins
Drum Scrubbers
> 5 mm (> 2 mm)
Screens 1
> 5 mm
> 1 mm
Screens 2
2-1 mm
Rodmil
Hydrocyclones 1
Hydrocyclones 2
Hydrocyclones 3
Thickeners
Hydroseparators
Coarse Flotation
Fine Flotation
Belt Filter
Belt Filter
Belt Filter
Tailings
A1 Concentrate 68 - 70% TCP
Waste Disposal
A3 Flotation Tailings
A3 Flotation Concentrate 75 - 77% TCP
Subcommercial Concentrate

Table 1

WHOLE SECTION ANALYSIS / NON COQUINA AREA
MINE No. 1
PHOSPHATIC LAYERS & INTERWASTES

Pit No.	TCP	CaO	SiO_2	R_2O_3	CaO / P2O5
166	46.24	32.10	27.68	2.66	1.518
172	44.02	30.64	30.50	2.94	1.520
179	47.30	32.82	29.30	4.11	1.520
190	56.15	37.47	23.15	3.68	1.458
191	52.56	35.74	30.90	2.89	1.480
192	46.84	31.53	31.19	6.13	1.470
194	46.92	32.00	29.96	3.64	1.494
195	47.59	31.97	34.12	2.28	1.468
196	43.80	29.70	37.10	4.30	1.482
199	47.60	32.23	31.73	4.07	1.480
201	37.20	25.70	38.20	5.14	1.510
202	39.68	27.90	34.84	5.56	1.534
205	42.43	28.76	31.28	6.34	1.481
207	46.81	31.31	32.60	5.44	1.460
Avg.	46.10	31.42	31.61	4.23	

Table 2

Variations In Chemical Compositions From Coquina Area Across Non Coquina Area For Phosphatic Layer A2 CA - Coquina Area NC - Non Coquina Area							
PIT NO.		TCP	CaO / P_2O_5	SiO_2	Al_2O_3	Fe_2O_3	Cl
156	CA	75.82	1.48	2.9	0.19	0.05	0.02
164	CA	74.07	1.50	3.7	0.16	0.07	0.05
172	NC	74.95	1.47	4.55	0.15	0.12	0.25
191	NC	66.27	1.44	12.000	2.05	1.25	0.09
18	NC	60.42	1.44	20.60	2.71	2.15	----

Table 3

Variations In Chemical Compositions From Coquina Area Across Non Coquina Area For Phosphatic Layer A2 CA - Coquina Area NC - Non Coquina Area							
PIT NO.		TCP	CaO / P_2O_5	SiO_2	Al_2O_3	Fe_2O_3	Cl
150	CA	72.32	1.49	4.0	0.14	0.08	0.02
158	CA	75.38	1.49	3.9	0.10	0.05	0.02
166	NC	72.26	1.48	3.00	0.14	0.13	0.15
199	NC	73.42	1.42	6.2	1.20	0.76	0.06
202	NC	66.70	1.42	13.0	3.84	2.60	0.17

Table 4

Physical And Chemical Analysis Of Channel Sample For Eshidiya Phosphate

Pit No.	- 1/2 #			F.Feed			Conc.		
	TCP%	AIR%	LOI%	TCP%	AIR%	LOI%	TCP%	AIR%	LOI%
847	42.04	39.34	4.48	63.20	18.19	3.76	80.37	2.05	3.65
848	55.02	26.16	3.96	51.93	31.93	3.51	77.28	2.96	4.82
849	41.26	42.34	3.50	45.79	40.74	2.96	76.12	5.29	3.29
850	49.50	33.70	3.30	56.68	29.14	2.52	80.65	2.98	3.24
851	33.17	51.20	4.31	38.14	48.43	3.28	71.54	8.91	5.21
852	41.55	38.78	4.98	47.38	38.82	3.42	78.04	3.95	4.24
853	47.27	28.88	6.08	58.85	22.23	3.76	78.43	2.24	4.30
854	45.70	38.96	3.08	52.07	33.56	2.44	80.14	3.05	3.19
855	44.92	43.12	2.22	42.96	47.59	1.85	80.76	2.28	3.27
856	42.96	44.80	2.39	36.12	55.40	1.59	79.11	4.11	3.33
857	40.48	45.56	3.17	45.16	42.54	2.65	78.92	4.51	3.63
858	41.71	39.14	4.78	45.99	36.92	4.85	72.49	4.04	6.45

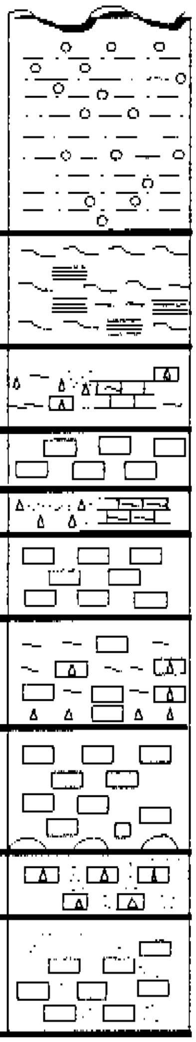
Table 5

CHEMICAL COMPOSITIONS OF PHOSPHATE PARTICLES SEPARATED FROM PHOSPHATIC LAYER A2 *

	Coquina Area	Non Coquina Area
P_2O_5	35.80	38.27
CaO	53.30	54.50
MgO	0.14	0.05
Al_2O_3	0.20	0.11
Fe_2O_3	0.05	0.72
SiO_2	0.62	0.57
SO_3	1.12	0.60
TiO_2	0.02	0.02
Na_2O	0.53	0.21
K_2O	0.05	0.003
F	4.08	4.13
Org. C.	0.13	0.14
LOI 1000 C	6.50	2.92
CaO / P_2O_5	1.4888	1.4241
Cd ppm	5	6

*** Separated By Heavy Liquid Separation .**

Eshidiya Mines
South Area - West Orebody
Pit No. [847]

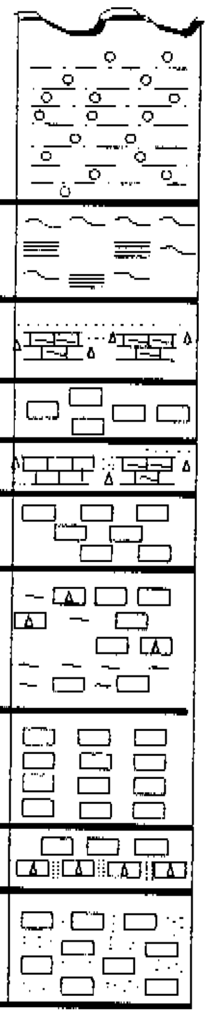


Depth (m)		Description
0.00		
4.00		Alluvium (Gravel , Sand , Silt).
5.80		Yellow Marl & Clay.
6.15	E	Marl Stone, Chert, Tripoli & Phtic Chert.
6.55	D	Soft Phosphate.
6.80	C	Marl Stone, Chert with Tripoli & Clay.
7.55	B	Soft & Medium Soft Phosphate.
8.70	IW1	H.Ph., Some reddish Ph., Phtic Chert, Marl & Fractured Chert at base.
9.85	A2	Friable Reddish Phosphate and nodules of Phtic. Cht. at base.
10.40	IW2	Hard Phosphate & Phtic Chert.
11.40	A3	Soft Reddish Sandy Phosphate.

D, C, B → A1

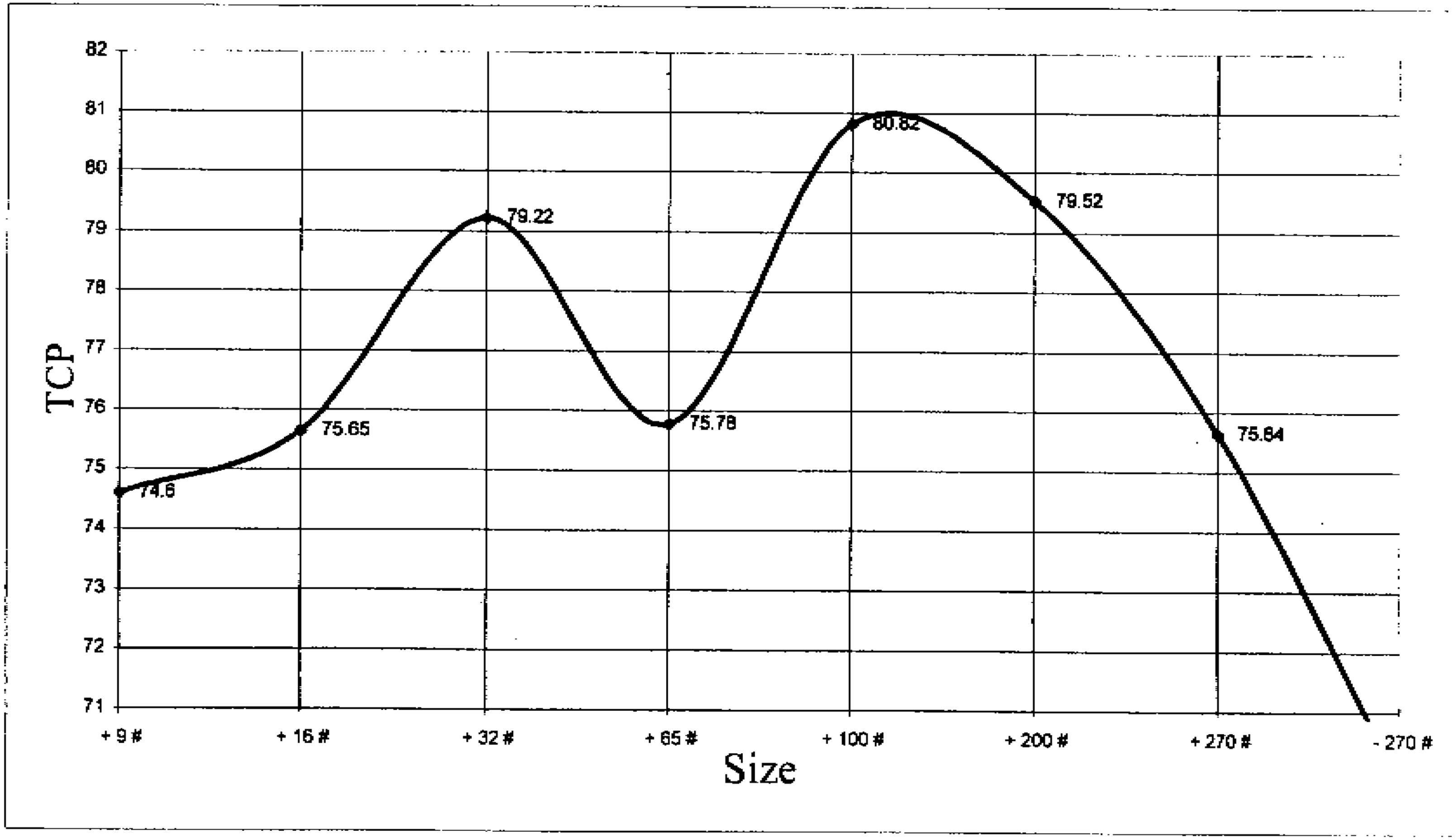
Note : Not to scale.

Eshidiya Mines
South Area - West Orebody
Pit No. [853]



Depth (m)	Unit	Descriptions
0.00 – 3.70		Alluvium (Gravel , Sand , Silt).
5.00		Yellow Marl & Clay.
5.40		Chert with Tripoli , Marl Stone.
5.75	D (A1)	Soft Reddish Phosphate.
6.00	C (A1)	Marl Stone & Chert with Tripoli.
6.80	B (A1)	Soft Reddish Phosphate.
8.00	IW1	Hard Phosphate , Phtic Chert , Marl , Clay & Fractured Chert.
9.30	A2	Friable Reddish Phosphate.
9.50	IW2	Hard Phosphate & Phtic Chert.
10.30	A3	Soft Reddish Sandy Phosphate.

Note : Not to scale.


TCP
82
81
80
79
78
77
76
75
74
73
72
71
74.6
75.65
79.22
75.78
80.82
79.52
75.64
+ 9 #
+ 16 #
+ 32 #
+ 65 #
+ 100 #
+ 200 #
+ 270 #
- 270 #
Size