Jordanian Phosphate Mining History

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ABSTRACT

Phosphate bearing deposits were first discovered in Jordan in 1908. It is estimated that more than 60% of the area of Jordan has phosphate-bearing deposits at varying depths. Jordanian Phosphate Mining Company (JPMC) predecessor commenced its phosphate mining activities in the Al Ruseifa area in 1935. Further mining operations were established in 1962 at Al Hassa and at Al Abiad in 1979. JPMC commenced excavation of a site at Eshidiya area in 1988, with production starting in 1989. This study show the Jordanian phosphate mining history according to previous and recent studies that have been already done from the early discovered phosphate until the recent days.

Keywords: Jordan, phosphate, mining, excavation, beneficiation.

INTRODUCTION

Phosphate rocks are the vital natural resources and the main source of phosphorus, which is one of the major plant nutrients. About 90% of the mined phosphate is used in agriculture. Phosphates of the Upper Cretaceous cover about 60% of the total area of Jordan (MacDonald, and Partners, 1965a, b). It lies near the surface within the entire area of the Upper Cretaceous (Campanian-Maastrichtian age), that form a wide phosphate belt stretching from north to south Jordan (Fig.1).

Phosphate deposits are localized in Ruseifa, Al-Hassa, Al-Abiad, and Eshidiya. In Al-Hassa and Al-Abiad the phosphate beds are found in two horizons in a lenticular shape, whereas in Ruseifa and Eshidiya mines they occur in continuous phosphate beds. Jordan Phosphate Mines Company was established as a private company in 1935, to exploit phosphate deposits in Rusaifa. In 1953, it became public share holding company. In 1963, Parson Corporation conducted exploration of phosphate in central Jordan. During the period 1973-1974, the Natural Resources Authority (NRA) as a part of UNDP/NRA Phosphate Exploration Program drilled many boreholes in the study area. Jordan Phosphate Mine Company undertook drilling in the area during 1970's and early 1980's. The Company started production in 1962 from Al-Hassa mine, located about 136km south of Amman. Production from Al-Abiad mine started in 1979 which is located about 20km north of Al-Hassa mine. In 1982, a fertilizer complex was constructed about 17km south of Aqaba to produce phosphoric acid, diammonium phosphate (DAP) and aluminum fluoride.

In 1988, the production started from Eshidiya mine, which is located about 70 km southeast of Ma'an city and 125 km northeast of Aqaba Port.

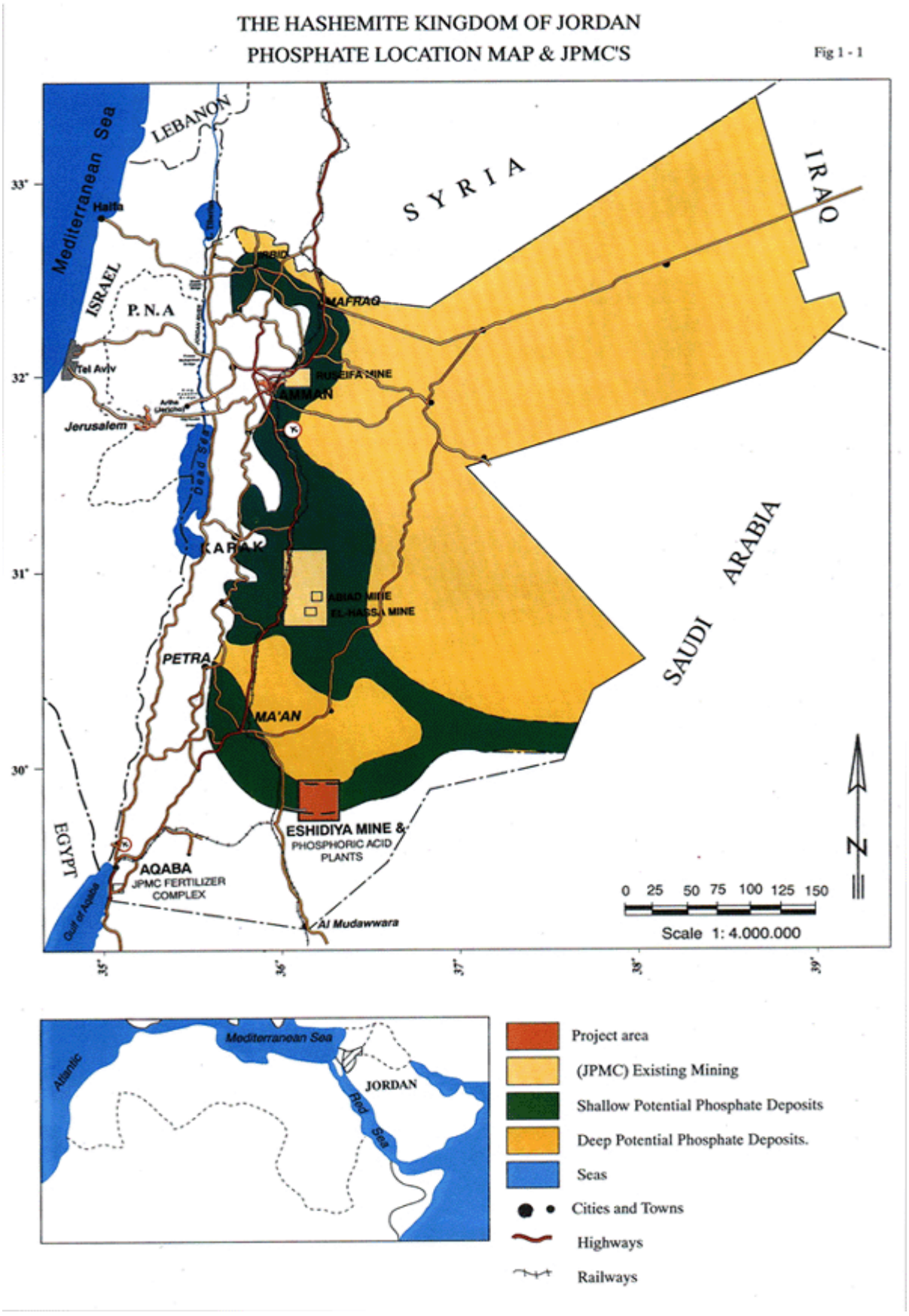

Figure 1. Phosphate location map in Jordan

MINERALOGY AND CHEMISTRY OF PHOSPHATE

The composition of the studied phosphate is made up of four types of phosphate particles as follows: pellets, intraclasts, skeletal fragments and coated grains. The phosphate particles occurring in the form of subrounded to subangular grains or pellets ranging in size from 0.2 to 0.5 mm. The matrix is mostly calcitic and locally silicic. The main diagenetic replacement of phosphate particles are calcitization and silicification. Francolite is the main phosphatic mineral identified by XRD, whereas calcite, quartz and dolomite are minor elements (Abed and Abdalla, 1998; Abed and Al-Agha, M., 1989; Abed and Fakhoury, 1996, Tarawneh and Moumani, 2006). Chemical analysis indicate that the P2O5 and other compounds are varying in different phosphate mines and depend on its concentration and association with other rocks in geological profile (Table 1).

MINING HISTORY AND EXPLORATION

Mining and exploration 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 after that loaded into dump trucks for hauling to crushing and screening plants. The mine at Al-Ruseifa commenced production in 1935. However, owing to the depletion of economically exploitable reserves, this mine has been dormant since 1985 and JPMC has no plans to recommence mining operations. The total quantity of phosphate produced during the year 2005 from this mine amounted to only 60 thousand ton, which was derived exclusively from existing stockpiles of mined ore. Al-Hassa and Al-Abiad mines are located approximately 20 km apart, some 130 km south of Amman. Each of the mines has a railway terminal linking it to the port at Aqaba. The mines at Al-Hassa and Al-Abiad, each covering an area of approximately 25 square km, were, until the development of Eshidiya in 1988, the main mining and production sites of JPMC. The mines at Al-Hassa and Al-Abiad produce two main grades of phosphate rock, although selective mining and blending can produce other grades. The principal grades produced are a standard grade 70/72 TCP, which requires only crushing and screening followed by drying of the mined ore, and a higher grade 73/75 TCP resulting from additional beneficiation by washing followed by subsequent drying to reduce the moisture content to a maximum of three percent.

The mining area of Eshidiya mine is carried out by open pit mining method. The overburden on each pit after drilling and blasting is removed by dragline and the phosphate layers are then selectively mined by means of hydraulic backhoes and drump trucks. The run of mines ores from the mining pits are then transported to screening and crushing plants, which will remove the +12.5mm oversize. The phosphate ores -12.5mm are temporarily stockpiled on a linear storage according to their layers A1, A2 and A3. The screened ores or mixture of ores from the mine storage are then conveyed to the mill site.

DEVELOPMENT OF ESHIDIYA MINE

In 1988, the production started from Eshidiya mine, which is located about 70 km southeast of Ma'an city and 125 km northeast of Aqaba Port. Detailed Drilling and geostatistical studies identified continuous phosphate bearing areas and a total geological reserves substantially, particularly in the northern, eastern and southeastern parts. Huge and new localities were studied in nearby areas as in Naqib Etaieq area (Tarawneh, 2005; Tarawneh and Moumani, 1998). Recently a fertilizer complex was constructed close to Eshidiya mine by the Indo-Jordan chemical Company to produce phosphoric acid since

1997 with capacity of 660000mt yearly. Eshidiya mine is considered as a potential area that contains huge geological ore reserves exceeding 1.2 billion tones in a very small locality. The criteria of phosphate deposits of Eshidiya is that it contains ore reserves, following beneficiation can yield approximately 400 million tones of concentrate to be sufficient for 40 years of continuous production at a production level of 10 million ton per year (MTPY). Depending on the intensive studies from 1985-1988, the area was substantially adjusted. These adjustments together with the consequent modifications on processing flow sheets have indicated that in average 3.23 MTPY of dry commercial grades can be produced throughout the 20 years life of the project from the modified area of 15.7 km^2.

Table 1. Chemical analysis of some selected phosphate samples from Jordanian Phosphate

No	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3	Total
1	**0.00**	**1.51**	**1.26**	**6.83**	**30.00**	**0.12**	**49.2**	**0.06**	**0.03**	**0.71**	**89.72**
2	**0.00**	**1.23**	**0.56**	**1.83**	**29.50**	**0.14**	**54.5**	**0.02**	**0.01**	**0.30**	**88.14**
3	**0.00**	**1.26**	**0.48**	**2.13**	**29.17**	**0.10**	**54.0**	**0.01**	**0.01**	**0.34**	**87.58**
4	**0.05**	**0.80**	**0.21**	**24.94**	**27.32**	**0.09**	**42.2**	**0.00**	**0.01**	**0.27**	**95.90**
5	**0.00**	**1.09**	**0.23**	**2.62**	**29.54**	**0.10**	**51.6**	**0.00**	**0.01**	**0.24**	**85.47**
6	**0.00**	**1.17**	**0.39**	**2.01**	**30.14**	**0.09**	**52.7**	**0.00**	**0.01**	**0.29**	**86.88**
7	**0.01**	**1.15**	**0.91**	**2.42**	**28.39**	**0.12**	**49.2**	**0.06**	**0.03**	**0.51**	**82.82**
8	**2.07**	**1.51**	**0.18**	**1.48**	**30.26**	**0.02**	**46.9**	**0.04**	**0.01**	**0.29**	**82.77**

ORE PHOSPHATE CHARACTERISTICS

The phosphate deposits of Eshidiya mine occur in continuous beds. According to the local nomenclature of JPMC Eshidiya phosphate deposits are founded at two horizons, the upper horizon (A0) and the lower horizon that consist of three main levels of phosphate from top to bottom: A1, A2 and A3.

The phosphate layer A1 produce concentrate grade of 68-70% TCP (P2O5 31-32%). The A2 layer produce concentrate grade of 73-75% TCP (P2O5 33.9-34.5%), while the A3 layer produce concentrate grade of 75-77% TCP (P2O5 34.1-35%). The horizon A2 subdivided into three sublevels (B, C and D). The lower horizon occupies an area of 125km^2 (Western and Eastern ore bodies), which is considered as a proven reserve for Eshidiya by Sofremines and JPMC. To achieve more reliability for the Eshidiya reserve and resources, an exploration and quality grade control drilling continues using Minex software, which was installed in JPMC in 1999. The model updated periodically for mining of the western ore body.

BENEFICIATION OF PHOSPHATE MINES

The phosphate bearing deposits at Eshidiya occur in continuous beds with a significantly reduced thickness of over-burden and, accordingly, a considerably lower stripping ratio than the mines at Al-Hassa and Al-Abiad, thereby rendering the mining and production process at Eshidiya more economical than at JPMC's other mines.

The phosphate bearing deposits occur in five layers at Eshidiya (layers A1, A2, and A3 throughout Eshidiya, including two layers in the Upper Horizon area (S1 and S2). The Eshidiya layers from ground level downwards are as follows:

- Layer A1, which produces phosphate concentrate grade of 68/70 TCP
- Layer A2, which produces phosphate concentrate grade of 73/75 TCP
- Layer A3, which produces phosphate concentrate grade of 75/77 TCP

The Upper Horizon layers from ground level downwards are as follows:

- Layer S1, which produces phosphate concentrate grade of 68/70 TCP
- Layer S2, which produces phosphate concentrate grade of 75/77 TCP.

Layer A1 requires treatment by washing and de-sliming to remove the clay content and subsequent drying. Layer A2 is a high-grade deposit, the majority of which requires no further treatment other than screening to achieve 73/75 TCP grade, as it has a high natural phosphate concentrate and a moisture content of less than three per cent. Layer A3 has a high silica content that requires flotation treatment to remove silica impurities in order to produce high-grade 75/77 TCP.

Layers S1 and S2 require washing treatment by single stage agitation to remove clay and reduce chlorine content, to produce medium grade (67/69TCP), in the case of layer S1, and high grade (75/77 TCP), in the case of layer S2.

Al Hussein Bin Talal University carries out new research dealing with the beneficiaton of phosphate with aim to find the optimum operating parameters for flotation of Jordanian phosphate that yield the highest recovery and concentrate grade. For this aim an attempt was made to explore the effect of collector dosage on the flotation performance of siliceous Jordanian phosphate for two different types of flotation feed; coarse feed (-1+0.5 mm) and fine feed (-0.5+0.053 mm). Flotation performance which was measured in terms of concentrate grade and recovery were correlated with collector dosage. In addition, collector dosage was correlated with number of cleaning stages required for each feed size range (Al- Thyabat, et al., 2007a, b). JPMC will be completing the rehabilitation of the equipment of beneficiation plant at Eshidiya Mines to increase the production of high-grade phosphate rock from the beds A1 and A3 by 1.3 million tones annually. JPMC will also develop the Upper Horizon ores with the aim of increasing production of high-grade phosphate by 1.3 million tones annually as of the first half of 2008.

In 2005, total phosphate rock produced by JPMC at Eshidiya amounted to 3.17 million mt.

The mines at Al-Hassa and Al-Abiad produce two main grades of phosphate rock, although selective mining and blending can produce other grades. The principal grades produced are a standard grade 70/72 TCP, which requires only crushing and screening followed by drying

of the mined ore, and a higher grade 73/75 TCP, resulting from additional beneficiation by washing followed by subsequent drying to reduce the moisture content to a maximum of three percent.

During the year ended 31 December 2005, the mines at Al-Hassa produced approximately 1.42 million mt of phosphate rock and Al-Abiad 1.73 million mt. JPMC's current production plan for these mines is gradually to reduce production levels at the mines at Al-Hassa and Al-Abiad over the next 5 years, although this production plan may be revised depending upon market demand and the level of prevailing international prices. Mines at Al-Hassa and Al-Abiad have relatively small proven reserves of 20 million and 19 million mt of phosphate-bearing ore deposits, respectively, and at projected rates of mining. JPMC is carrying out ongoing exploration at both mines in order to ascertain whether the useful life of the mines may be capable of being extended, although this will depend on the quality, formation and accessibility of any additional phosphate-bearing ore discovered.

EXPLORATION AND ORE RESERVES

The Jordanian Natural Resources Authority estimates that Upper Cretaceous including phosphate formations cover approximately 60% of the total area of Jordan, principally in a 300 km wide belt running from north to south with the majority of economically viable reserves lying in the Eshidiya region (Sunna, 1974) . JPMC has an on-going exploration programme, focusing principally in the Eshidiya region; JPMC bases its exploration programme on geological data from the Jordanian Natural Resources Authority following initial testing procedures and its own field observations and aerial surveys. The exploration process involves drilling boreholes to depths of approximately 40 m at measured distances from one another followed by technical qualitative and quantitative analysis of ore samples. Deposits are classified as reserves in circumstances where phosphate-bearing deposits of a suitable quality and quantity are located. Reserves are categorized as "proven" where ore of adequate quality and quantity is established in an area where boreholes are drilled at distances of 100 m apart, "indicated" where the distance between boreholes is 400 m and "inferred" where the distance between boreholes is in excess of 400 m (Table 2).

In addition to qualitative and quantitative testing, JPMC also tests the depths of the overburden and the depth of the layers of phosphate bearing ore to establish an approximate stripping ratio using samples extracted from boreholes in order to establish the economic viability of the reserves. Generally, JPMC considers that an overburden in excess of 50 m deep is likely to be the limit of economic viability of the underlying deposits, although this can vary depending upon mining techniques used and the quality of the phosphate bearing deposits.

JPMC currently has exploration and mining licenses covering a total area of 52 square km at the mines at Al-Hassa and Al-Abiad and 258 square km at Eshidiya.

Table 2. Estimated total reserves of phosphate ore in three operating mines (JPMC, 2005):

Location	Proven	Indicated	Inferred	Total
	(million ton)			
Al-Abiad	21	26	52	99
Al-Hassa	26	0	0	26
Eshidiya	710	280	350	1340

ENVIRONMENTAL GEOCHEMISTRY

Phosphate rock deposits in Jordan are sedimentary in origin and have a high $P_2 0_5$ content capable of producing high-grade TCP concentrate phosphate rock. One of the significant environmental and competitive aspects of Jordanian phosphate rock is its relatively low concentration of heavy metals such as cadmium, lead, mercury, arsenic and zinc, all of which are considered to be environmentally hazardous, particularly cadmium. There has been a significant increase in awareness in recent years of the potentially adverse environmental impact of heavy metals in fertilizers, which, following application, can lead to high levels of contamination in the soil and rivers, coupled with the possibility of uptake by agricultural products. Accordingly consuming countries, particularly European and OECD countries including Australia, New Zealand and Japan, have introduced limits in relation to the heavy metal content of fertilizers and JPMC believes that in the future permitted cadmium levels are likely to continue to be reduced as concern as to the environmental effects, particularly of cadmium contamination, increases.

Cadmium levels of 15 parts per million ("ppm") are generally considered to be hazardous and a number of European countries have introduced limits as low as 10 ppm of cadmium for phosphate rock imports. The cadmium content of JPMC's phosphate rock is less than 10 ppm and JPMC believes that this is, and is increasingly likely to become, an important competitive feature in world markets. JPMC believes that the low cadmium content of its phosphate rock gives it a competitive advantage over other major exporters of phosphate rock.

In addition, Jordanian phosphate rock contains low levels of other substances, which are regulated in many countries, including, arsenic, lead, mercury, uranium and zinc. The uranium content of phosphate rock produced by JPMC ranges from between 70 to 80 ppm at Al-Hassa and Al-Abiad and between 40 to 60 ppm at Eshidiya.

CONCLUSIONS:

Phosphate rocks are the vital natural resources and the main source of phosphorus, which is one of the major plant nutrients. About 90% of the mined phosphate is used in agriculture. Phosphates of the Upper Cretaceous cover about 60% of the total area of Jordan (MacDonald, and Partners, 1965a, b). It lies near the surface within the entire area of the Upper Cretaceous (Campanian-Maastrichtian age), that form a wide phosphate belt stretching from north to south. Phosphate deposits are localized in Ruseifa, Al-Hassa, Al-Abiad, and Eshidiya. In Al-Hassa and Al-Abiad, the phosphate beds are found in two horizons in a lenticular shape, whereas in Ruseifa and Eshidiya mines they occur in continuous phosphate beds. The composition of the studied phosphate is made up of four types of phosphate particles as follows: pellets, intraclasts, skeletal fragments and coated grains. Francolite is the main phosphatic mineral identified by XRD, whereas calcite, quartz and dolomite are minor elements. Mining

and exploration 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 after that loaded into dump trucks for hauling to crushing and screening plants. The phosphate bearing deposits at Eshidiya occur in continuous beds with a significantly reduced thickness of over-burden and, accordingly, a considerably lower stripping ratio than the mines at Al-Hassa and Al-Abiad, thereby rendering the mining and production process at Eshidiya more economical than at JPMC's other

mines. One of the significant environmental and competitive aspects of Jordanian phosphate rock is its relatively low concentration of heavy metals such as cadmium, lead, mercury, arsenic and zinc.

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REFERENCES

Abed and Fakhoury 1996. On the chemical variability of some phosphatic particles from Jordanian phosphorites. Chemical Geology 131:1-13.

Abed and Abdalla 1998. On the state of weathering of upper cretaceous red phosphorites of Eshidiya, southern Jordan. Journal of African Earth Science 27: 39–54.

Abed and Al-Agha 1989. Petrography, geochemistry and origin of the NW Jordan phosphorites. Journal of Geological Society London 146: 499–506.

Al-Thyabat, Tarawneh, Harareh, Rawashdeh, Ryan and Majali, 2007 b. Beneficiation of Jordanian phosphate: A review of current practices. The fifth international Jordanian mining conference, Amman, Jordan.

Al-Thyabat, Rawashdeh, Majali and Ryan 2007a .The effect of collector dosage, particle size and impeller speed on the performance of Jordanian phosphate flotation: Lab scale study. Flotation 07, Cape Town, South Africa.

Jonathan 2000. Recent advances in mine planning at JPMC. Proceeding of The third Jordanian International Mining Conference. Jordan Engineers Association. Amman.

MacDonald and Partners 1965a. East Bank Water Resources, six volumes, Central Water Authority, Amman MacDonald and Partners, 1965b. East Bank Water Resources. Hydrological survey of the Madaba-Ma'an area, 3 volumes, Central Water Authority, Amman.

Tarawneh and Moumani, 1998. Geological and Mineralogical Studies on the Phosphorite Deposits in Naqib Etaiq/SE Jordan, Proceeding of the 6th Jordanian Geological Conference, pp. 19-33, Amman.

Tarawneh 2005. Geological Map of Wadi Abu Mil area (Esh Shidiya Phosphate Mine), Map Sheet No. 3249-IV, NRA,

Tarawneh and Moumani (2006). Petrography, chemistry and genesis of the early Eocene phosphorite concretions from Ma'an area/South Jordan. Journal of Asian Earth Science 26: 627-635.

Sunna 1974. Phosphate exploration and beneficiation studies (Project Jordan 70/521). Unpubl. Report. NRA., Amman.