



## **DEVELOPMENT OF THE PHOSPHATE INDUSTRY IN IRAQ: RESOURCES, REQUIREMENTS AND CHALLENGES**

**Khaldoun S. Al-Bassam<sup>1</sup>**

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### **ABSTRACT**

The extensive geological and mineral exploration works in Iraq revealed large resources of potentially economic marine sedimentary phosphate deposits in the Western Desert. The indicated resources are estimated by about 10 billion tons, whereas the reserves are over 5 billion tons of phosphate rocks with 20 – 22 % P<sub>2</sub>O<sub>5</sub> content. Phosphate mining has started by the Iraqi government in the Akashat deposit in the early eighties of the past century with a designed capacity of 3.4 Mt/year to feed the fertilizers plant at Al-Qaim, designed to produce 1 Mt of fertilizers/year. Since 1991, the development of phosphate industry in Iraq faced serious problems which hindered the commissioning of new mines and expanding fertilizers production. Moreover, mining in Akashat and fertilizers production at Al-Qaim have almost stopped after 2003. The availability of large phosphate reserves with suitable specifications and feasible mining and beneficiation conditions call for immediate measures to start new mining projects and fertilizers production plants, as well as rehabilitation of the available facilities, to be implemented by partnership of the government with the private sector. Modern technologies should be introduced to ensure best practices in mining, beneficiation and fertilizers industry, in addition to maintaining safe and clean environmental conditions. Guidelines for future development of phosphate industry in Iraq are presented in this paper including potential deposits for exploitation, conditions for licensing, requirements of the new projects, production capacities, products and by-products, environmental protection and economic impact.

### **تطوير صناعة الفوسفات في العراق: المصادر والمتطلبات والتحديات**

**خلدون صبحي البصام**

#### **المستخلص**

اثمرت عمليات الاستكشاف الجيولوجي والمعدني في العراق عن اكتشاف موارد كبيرة من خامات الفوسفات الرسوبية البحرية في الصحراء الغربية العراقية وتقدر الموارد المؤشرة من هذه الرواسب بحوالي 10 بليون طن في حين تزيد الاحتياطيات عن 5 بليون طن من الصخور الفوسفاتية بمعدل يتراوح بين 20 و 22% من خامس أكسيد الفوسفور. باشرت الحكومة العراقية باستخراج الفوسفات من منجم عكاشات في مطلع عقد الثمانينات من القرن الماضي بطاقته تصميمية بلغت 3.4 مليون طن في السنة لتغذية مجمع القائم المصمم لإنتاج 1 مليون طن من الأسمدة سنويا. منذ 1991 واجه تطوير الصناعة الفوسفاتية في العراق مشاكل جديده ساهمت في عدم فتح مناجم جديده و بالتالي عدم التوسع في إنتاج الأسمدة الفوسفاتية فضلا عن أن استخراج الفوسفات من مناجم عكاشات وإنتاج الأسمدة في القائم توقفا تقريبا بعد

<sup>1</sup> Scientific researcher, Czech Geological Survey, Prague, Czech Republic (former director of Iraq Geological Survey), e-mail: [albassam703@gmail.com](mailto:albassam703@gmail.com)

عام ٢٠٠٣. إن توفر احتياطيات كبيره من الصخور الفوسفاتية بمواصفات مناسبة وظروف منجمية وإثرائية متاحة تستدعي إجراءات عاجله للمباشرة بمشاريع استخراجية جديدة لتغذية معامل جديدة لإنتاج الأسمده الفوسفاتية فضلا عن تأهيل المرافق المقامة سابقا عن طريق المشاركة بين الحكومة والقطاع الخاص على أن تضمن هذه المشاريع استخدام التقنيات الحديثة في الاستخراج وإثراء الخام وصولا الى إنتاج الأسمده الفوسفاتية فضلا عن ضمان سلامة ونظافة البيئة من التلوث. نقترح في هذه الورقة عدة نقاط إرشادية لمشاريع التطوير المستقبلي للصناعة الفوسفاتية في العراق بما في ذلك الرواسب الفوسفاتية المرشحة للاستثمار ومتطلبات منح الرخص الاستثمارية للمشاريع الجديدة والطاقت الإنتاجية المستهدفة والمنتجات الأساسية والمنتجات المرافقه الممكنة ومتطلبات المحافظة على البيئة فضلا عن الآثار الاقتصادية المتوقعه لهذه المشاريع.

## INTRODUCTION

It has been more than 65 years since phosphate rocks were discovered in Iraq, yet mining and fertilizers industry are limping and suffering from various obstacles hindering their development to the levels that corresponds to the large reserves available and the need of the country to meet agricultural demand for fertilizers as well as to enhance the non-oil economic revenues of the country. More than 35 years have passed since the first and only phosphate mine and fertilizers plant were commissioned, yet only about 20 million tons of phosphate raw material have been mined. New resources and reserves have been discovered and assessed in the period 1986 – 1990 which increased the indicated phosphate resources to about 10 billion tons, more than 50% of which are proved reserves (Al-Bassam *et al.*, 1990; Al-Bassam *et al.*, 2012).

All the new deposits lie at the northern and western sides of the Ga'ara Depression (Fig.1). The largest of these deposits is Swab with about 3500 Mt of reserves (Table 1). Most of the new deposits are found within the Akashat Formation (Paleocene) and resemble the Akashat phosphate deposit in their grade, textural, petrological and mineralogical characteristics. They have higher stripping ratios, but they are all amenable for open pit mining methods. They can be beneficiated to the required industrial grade by calcination and disliming and one of them, the Hirri deposit (Area 1), can be beneficiated by simple sizing techniques (Al-Ajeel and Hammody, 1989; Al-Ajeel and Dayekh, 1989; Hammody, 2005). Projects to exploit this specific deposit were planned and started in 1990, but they were terminated after the Gulf war. Since then nothing has been done to renew these efforts and to benefit from the available wealth of phosphate resources in Iraq. The adapted and announced investment policy of the Iraqi Government after 2003 permits and encourages private sector participation which can be the main player in the future development of the phosphate industry in Iraq when a healthy and transparent investment policy is adapted by the government.

Table 1: Phosphate reserves and indicated phosphate resources of Iraq  
(see Fig.1 for location)

| Deposit and age     | Reserve/<br>Resource (m.t) | P <sub>2</sub> O <sub>5</sub><br>(%) | Exploration category* and reference          |
|---------------------|----------------------------|--------------------------------------|--|
| Akashat (Paleocene) | 430.0                      | 21.52                                | A + B + C1 (Al-Khalil <i>et al.</i> , 1973)  |
| Swab (Paleocene)    | 3502.9                     | 21.71                                | C1 (Al-Bassam, 1988a)                        |
| Dwaima (Paleocene)  | 2758.0                     | 20.56                                | C1 + C2 (Al-Bassam and Saeed, 1990)          |
| Marbat (Paleocene)  | 2114.2                     | 21.17                                | C1 + C2 (Gulli, 1989)                        |
| Hirri (Paleocene)   | 193.0                      | 21.94                                | B (Al-Bassam <i>et al.</i> , 1989a and b)    |
| H 3 ( Paleogene)    | 313.0                      | 17.50                                | A + B + C1 + C2 (Antonets and Aksenov, 1962) |
| Ethna (Eocene)      | 430.0                      | 17.50                                | C2 (Abdul Raheem, 1983)                      |
| <b>TOTAL</b>        | <b>9741.1</b>              |                                      |  |

\*Russian norms

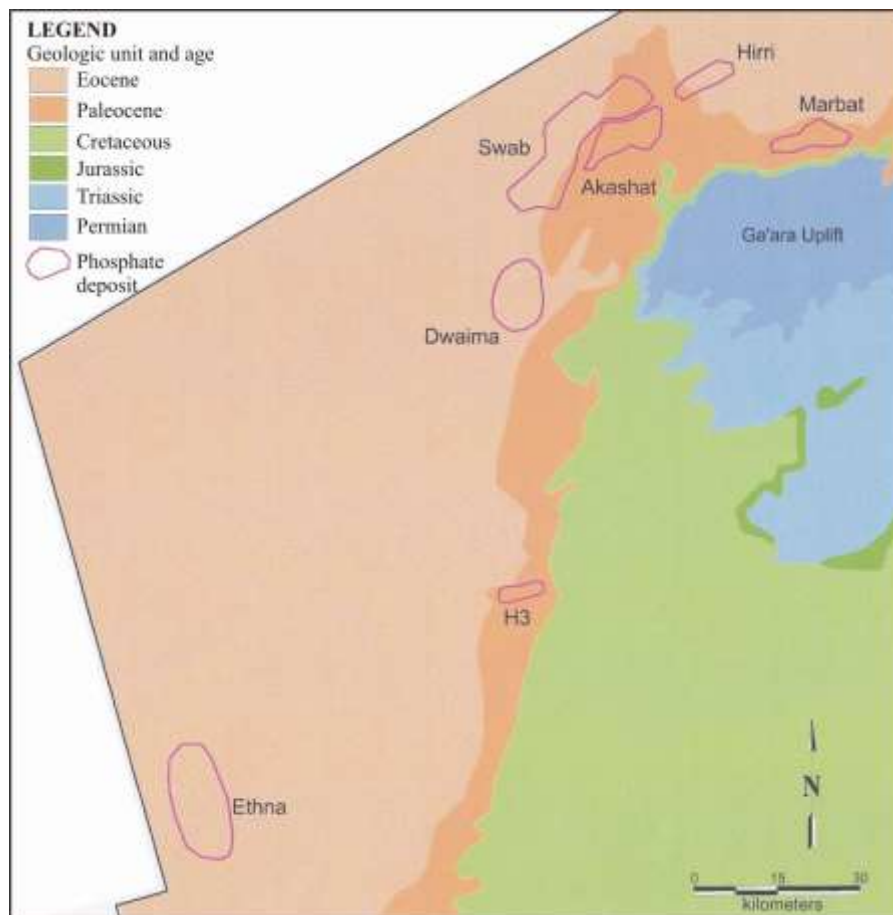


Fig.1: Geological map of western Iraq and location of phosphate deposits  
(Al-Bassam *et al.*, 2012)

## PHOSPHATE DEPOSITS OF IRAQ

These are summarized somewhere else in this issue (Al-Bassam, 2017; this issue), but more details on main deposits are given here. The Iraqi indicated reserves/resources are distributed in seven explored deposits: Akashat, Swab, Hirri, Marbat, Dwaima, H3 and Ethna (Fig.1). The H3 deposit was discovered by Cobett (1954) and the first to be investigated in the sixties of the last century (Antonets and Aksenov, 1962), whereas the giant deposits of Swab, Marbat and Dwaima were the fruits of the later more comprehensive exploration campaign of the eighties (Al-Bassam *et al.*, 1990). Mining has been active since the early eighties from the Akashat deposit only. All the investigated resources are of Paleocene age, except the Ethna deposit, which is Eocene.

### ▪ Akashat Deposit

The Akashat phosphate deposit lies about 100 Km NNW of Rutba town, in the NW part of the Western Desert and covers an area of about 100 Km<sup>2</sup>. Two main phosphorite beds were identified; both are within the Akashat Formation (Paleocene). The lower bed; 1 – 2 m thick, is part of the Traifawi Member and the upper bed; 8 – 10 m thick, is part of the Hirri Member. The interbed is phosphatic shelly limestone; 0 – 2 m thick. The mining procedure considered both phosphorite beds and the phosphatic limestone interbed as one mineable industrial bed, with 21 – 22 % P<sub>2</sub>O<sub>5</sub>.

The phosphate grains (mostly peloids, ooids and bioclasts) constitute about 60 – 65 % of the industrial bed and the remaining is mainly calcite with minor clays and quartz. The phosphate grains contain 32 – 33 % P<sub>2</sub>O<sub>5</sub> and are composed of carbonate-fluorapatite (francolite). The mineral constituents include, beside the apatite, calcite, quartz, smectite and palygorskite. In weathered parts of the deposit some gypsum and halite may be present. The average chemical composition (in wt. %) is: P<sub>2</sub>O<sub>5</sub> 21.5, CaO 51.2, MgO 1.0, SrO 0.17, SiO<sub>2</sub> 1.7, Fe<sub>2</sub>O<sub>3</sub> 0.2, Al<sub>2</sub>O<sub>3</sub> 0.4, Na<sub>2</sub>O 0.76, K<sub>2</sub>O 0.05, SO<sub>3</sub> 1.4, F 2.5 Cl 0.12, CO<sub>2</sub> 18.3, H<sub>2</sub>O 1.0. Trace elements (in ppm) include: U 42, Cd 67, V 117, Y 45, Cu 16, Cr 212, Ni 42 and Zn 444 (Al-Bassam, 1976; Al-Bassam, 1988b).

#### ▪ **Swab Deposit**

This is the largest single phosphorite deposit in Iraq, discovered and investigated in 1986 – 1987 (Al-Bassam, 1988a). It is located to the west of Akashat deposit; separated by Wadi Al-Hirri, and forms an elongated plateau, extending for about 30 Km in a NE – SW direction and is 5 – 7 Km wide. The total area investigated is about 180 Km<sup>2</sup>; covered by 153 exploration boreholes, in a (1 × 1) Km net, (60) trenches along the slopes of the plateau, sampling and analysis of about (3000) samples (at 1 m interval) and geophysical gamma logging of all boreholes.

The economic bed is 9 – 16 m thick (average 11.2 m) and forms the natural geological extension of the Akashat deposit (Paleocene) in the NW direction. The phosphorite is granular (peloids, ooids and cortoids) in texture, cemented by calcite, slightly bituminous in deep sections. The overburden is (0 – 70) m thick (average 37 m); increasing from SW to NE, and consists of shelly limestone, lime mudstone with chert nodules, marl, shale and coprolitic limestone (Akashat Formation) and nummulitic limestone (Ratga Formation).

The average chemical composition of Swab deposit (wt.%) is: P<sub>2</sub>O<sub>5</sub> 21.7, CaO 51.25, MgO 1.1, SrO 0.19, SiO<sub>2</sub> 1.65, Fe<sub>2</sub>O<sub>3</sub> 0.2, Al<sub>2</sub>O<sub>3</sub> 0.38, Na<sub>2</sub>O 0.78, K<sub>2</sub>O 0.06, SO<sub>3</sub> 1.15, F 2.62, Cl 0.05 and L.O.I 19.7. Trace elements include (ppm): U 37, Y 89, V 172, Cd 55 Cr 269, Ni 72, Cu 25 and Zn 501.

#### ▪ **Dwaima Deposit**

This is the SW extension of Swab Deposit (Fig.1). It was identified and assessed separately for being a slightly siliceous phosphorite deposit. It occupies an area of 150 Km<sup>2</sup>; morphologically a plateau covered by the Lower Eocene nummulitic limestone of Swab Member (Ratga Formation) and dissected by Wadi Al-Hirri.

The deposit was investigated by drilling of 31 boreholes and sampling of core at 1.0 m interval (Al-Bassam and Saeed, 1988). The economic phosphorite bed is part of the Akashat Formation and it is equivalent to those in Akashat and Swab deposits; comprised of the upper part of the Traifawi Member and lower part of the Hirri Member. However, the upper part of the economic bed is characterized here by the presence of several thin bands of silicified phosphorite interbedded with the calcareous phosphorite.

The thickness of the economic bed ranges from 8.1 to 13.4 m (average 10.6 m). It consists of several alternations of friable phosphorite, cemented phosphorite, silicified phosphorite and phosphatic limestone. The average chemical composition of Dwaima deposit (in wt %) is: P<sub>2</sub>O<sub>5</sub> 20.56, CaO 50.76, MgO 0.84, SiO<sub>2</sub> 4.5, Fe<sub>2</sub>O<sub>3</sub> 0.21, Al<sub>2</sub>O<sub>3</sub> 0.28, Na<sub>2</sub>O 0.76, K<sub>2</sub>O 0.05, SO<sub>3</sub> 1.01, F 2.59, Cl 0.05, L.O.I. 19.14 and U 36 ppm. The grade of Dwaima

deposit is generally similar to that of Akashat and Swab deposits, except for the relatively higher silica content; especially in the southern part of the deposit.

#### ▪ Marbat Deposit

This deposit is located in the northern parts of the Ga'ara depression (Fig.1), elongated in an E – W direction and covering an area of 170 Km<sup>2</sup>. The deposit was investigated by drilling of 174 boreholes and about 50 trenches (Gulli, 1989). The Marbat deposit consists of three economic phosphorite beds; all are within the Akashat Formation of Paleocene age. The upper bed is 6.4 m. thick and the middle and lower beds are 0.7 and 2.2 m. thick respectively. The overburden consists of shelly limestone, chert-bearing lime mudstone and nummulitic limestone of Paleocene and Eocene age. The innerburden consists of shelly phosphatic limestone and siliceous dolomicrite with borings, overlying the middle and lower phosphorite beds respectively.

The average chemical composition of the three economic phosphorite beds is as follow (in wt.%):

Upper Bed: P<sub>2</sub>O<sub>5</sub> 21.25, CaO 51.39, MgO 1.66, SiO<sub>2</sub> 1.38, Fe<sub>2</sub>O<sub>3</sub> 0.18, Al<sub>2</sub>O<sub>3</sub> 0.23, Na<sub>2</sub>O 0.52, K<sub>2</sub>O 0.06, SO<sub>3</sub> 0.60, F 2.57, Cl 0.06, L.O.I 20.6 and U 23 ppm.

Middle Bed: P<sub>2</sub>O<sub>5</sub> 20.97, CaO 51.77, MgO 0.84, SiO<sub>2</sub> 1.68, Fe<sub>2</sub>O<sub>3</sub> 0.14, Al<sub>2</sub>O<sub>3</sub> 0.23, Na<sub>2</sub>O 0.51, K<sub>2</sub>O 0.04, SO<sub>3</sub> 0.66, F 2.41, Cl 0.06, L.O.I 21.1 and U 29 ppm.

Lower Bed: P<sub>2</sub>O<sub>5</sub> 21.00, CaO 44.69, MgO 1.38, SiO<sub>2</sub> 13.39, Fe<sub>2</sub>O<sub>3</sub> 0.37, Al<sub>2</sub>O<sub>3</sub> 0.62, Na<sub>2</sub>O 0.59, K<sub>2</sub>O 0.06, SO<sub>3</sub> 0.82, F 2.11, Cl 0.06, L.O.I 14.61 and U 35 ppm.

#### ▪ Hirri Deposit (Area-1)

This deposit is located 15 – 20 Km. NE of Akashat mine, occupying an area of about 35 Km<sup>2</sup>. The deposit was investigated by drilling of 185 boreholes (500 × 500 m. net) and sampling of core at 0.5 m. intervals (Al-Bassam *et al.*, 1989a; 1989b). The economic phosphorite bed lies at the base of the Upper Paleocene Dwaima Member of the Akashat Formation and ranges in thickness from 0.5 m. in the southern part to 4.5 m. in the central and northern parts. The average thickness is about 3.0 m. The overburden consists of 0 – 55 m thick chert-bearing lime mudstone, marl and nummulitic limestone of Upper Paleocene and Lower Eocene age. The thickness of overburden increases from south to north and the strata dip gently (less than 1°) to the NNE. The mineralogy of the deposit is comprised of 65% francolite, 20% dolomite, 8 % calcite, 4 % palygorskite and 3 % quartz. The average chemical composition of the deposit (in wt.%) is: P<sub>2</sub>O<sub>5</sub> 21.94, CaO 47.16, MgO 4.12, SrO 0.16, SiO<sub>2</sub> 2.80, Fe<sub>2</sub>O<sub>3</sub> 0.32, Al<sub>2</sub>O<sub>3</sub> 0.48, Na<sub>2</sub>O 0.76, K<sub>2</sub>O 0.06, SO<sub>3</sub> 1.31, F 2.71, Cl 0.10, L.O.I 18.88, U 45 (ppm) and Cd 23 (ppm).

The reserves were estimated at category B by 193 m.t. of phosphorite. The stripping ratio varies from 3 in the southern part; 6 in the middle part and 12 in the northern part. The deposit is characterized by several features as compared to the phosphorite deposits of Akashat, Swab, Dwaima and Marbat. The phosphate components are significantly coarser in grain size than the matrix. In addition, the economic bed is friable and contains no barren interbeds, with well defined and sharp lower and upper boundaries. Moreover, the Hirri deposit overlies the NE part of the Swab deposit; forming two mineable phosphate deposits in a single site.

The loose and friable character of the economic phosphorite makes it possible to upgrade the phosphate by simple beneficiation procedures depending on size differentiation and classification. Wet sieving laboratory tests proved successful in the upgrading of the

phosphorite of this deposit to about 30 %  $P_2O_5$  and less than 1 % MgO, with a  $P_2O_5$  recovery of 70 – 80 % and weight recovery of 50 – 60 % (Al-Ajeel and Hammody, 1989; Al-Ajeel and Daykh, 1989; Hammody, 2005). The average chemical composition of the concentrate (in wt.%) is:  $P_2O_5$  30.2, CaO 55.44, MgO 0.73, SrO 0.19,  $SiO_2$  0.88,  $Fe_2O_3$  0.16,  $Al_2O_3$  0.22,  $Na_2O$  1.19,  $K_2O$  0.05,  $SO_3$  2.17, F 3.49, Cl 0.05, L.O.I 10.21, U 60 (ppm) and Cd 17 (ppm).

### **EXPLOITATION OF THE IRAQI PHOSPHATE DEPOSITS**

Mining conditions of the Iraqi phosphorite deposits are relatively easy and feasible by open cast mining. The rocks are soft to medium tough and the average stripping ratio varies from 1, as in the Akashat deposit, to 3 as in the Swab deposit. The first and only phosphorite deposit mined in Iraq is the Akashat deposit. Actual mining started in 1983 from two quarries with a total designed capacity of 3.4 m.t/year. However, over more than 30 years of mine production the total excavated raw material was only about 20 million tons which is less than 20% of the designed capacity for that period and less than 5% of the total proved reserves of the deposit (Fig.2).

The simple mineralogy of the Iraqi phosphorites, where the major gangue mineral is calcite, facilitates simple beneficiation process by calcination, washing and desliming to upgrade the phosphates from 20 – 22%  $P_2O_5$  to > 30%  $P_2O_5$ . This beneficiation route has been applied for the Akashat phosphate and can be suitable for the other deposits of similar mineralogical and textural criteria. However, the Hirri deposit has an advantage in this respect; being a friable phosphorite with a distinct size difference between the phosphate components (coarser) and the cementing material (finer).

The phosphate concentrate of Akashat deposit is used since 1983 in the production of various types of phosphate fertilizers at Al-Qaim fertilizer plant; including TSP, NPK and NP. The main stage in this process is the production of phosphoric acid by the acidulation of the phosphate concentrate by sulfuric acid. The acid is concentrated to meet the requirement of the TSP plant. The process uses native Iraqi sulfur from Mishraq fields, or sulfur produced in the Iraqi oil and gas industry.

By-products include sodium fluoride and uranium oxide (yellow cake) together with the potential extraction of several metals from phosphoric acid; including: cadmium, zinc and REE. However, one of the major problems in the phosphate fertilizer industry in Iraq and elsewhere in the world is the huge amounts of phosphogypsum produced in the dissolution of the phosphate concentrate by sulfuric acid. This solid waste is fine-crystalline and rich in phosphoric acid, fluoride and some heavy metals. It is the main environmental hazard of this industry. Nearly 2 tons of phosphogypsum are produced for each ton of phosphate concentrate treated with sulfuric acid, and each ton of phosphoric acid produced is accompanied by 4.5 tons of phosphogypsum (Borris and Boody, 1980). The gypsum produced contains traces of phosphorus, fluoride, heavy metals and nuclides of the radioactive series of uranium (Al-Nuzal, 2017; this issue).

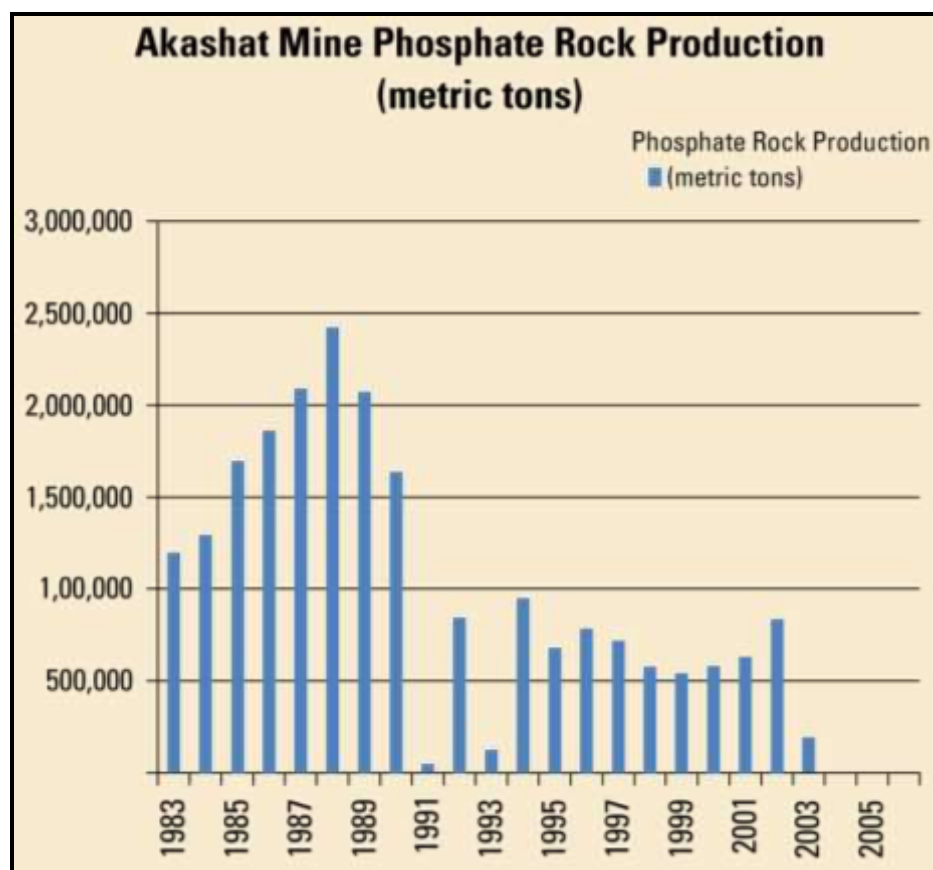


Fig.2: Phosphate rock mining at Akashat (1983 – 2003) (metric tons)  
(Al-Bassam *et al.*, 2012; based on archives of the State Co. for Phosphate,  
Ministry of Industry and Minerals, Iraq)

### CHALANGES FACING EXPLOITATION OF PHOSPHATE DEPOSITS IN IRAQ

Over more than half a century of geological exploration, financed by Iraqi government, the phosphorite resources of Iraq have been defined and assessed, but the government, who controls mineral industry in Iraq including that of phosphates, failed for many reasons, to create investment projects that are proportional to the huge resources defined and only limited efforts have been made to make use of this natural wealth in industry. The private sector was kept away from these projects and a state owned company is in charge of mining, processing and production of phosphate fertilizers for the past 35 years.

The private sector, limited to local Iraqi investors, is only active in simple quarrying of building raw materials. Mineral investment is governed in Iraq by the old legislation (Law no. 91 for the year 1988). This law stresses the control of the state on the mineral investment and does not encourage private sector involvement in major mining projects. Iraq Geological Survey is the authority (by law) to license mineral investment projects. In the recent years serious attempts were made to modify the mineral investment law, but Iraqi and non-Iraqi investors in mining still face serious problems related to procedures, bureaucracy, legislations, old-fashioned banking system, among other obstacles. The available phosphorite reserves and resources are much larger than the present exploitation rates which highlight the necessity of involvement of private Iraqi and foreign mining and fertilizers-producing companies in the exploitation of Iraqi phosphate deposits beside the Iraqi government.

Mineral industry in Iraq has significantly slowed down over the past two decades and, at present time, does not represent a significant contribution to the National economy. Several factors are involved in this setback, among which are: **1)** Licensing for mineral investment is a time consuming and complicated process; **2)** Unavailability of clear government policy and work procedures in the mining investment process; **3)** The government has stopped investing in the mining sector; **4)** Unavailability of important infrastructures vital for promoting investments (energy, transport, water); **5)** Unavailability of some important local expertise in the business, such as mining engineers and mining geologists.

### **GUIDELINE FOR THE GOVERNMENT AND PRIVATE SECTOR**

The Iraqi phosphate deposits have been classified as either indicated resources or as reserves (Al-Bassam *et al.*, 2012). These are considered as defined deposits when investment opportunities and licensing are announced. Consequently they do not follow the rule “first come first get” usually followed in the licensing for undefined deposits or regional exploration projects for blind deposits. The government should publically announce the investment opportunities in phosphate exploitation that should include the government conditions and norms together with sufficient documents on the geology of the deposits offered, enough to help and encourage the investors to apply. The government should study all offers with integrity and transparency and eventually the best offer that meets the conditions and norms should be selected and announced.

The main target of new exploitation projects should be the downstream industries; mainly phosphate fertilizers and by-products and not marketing raw material (excluding phosphate concentrates). Investors applying for licensing should submit credentials supporting experience and competence in the field of phosphate industry as well as credentials on financial capability relevant to the size and scope of the project. They need to submit a preliminary economic and technical feasibility of the project as well as a preliminary environmental- and social-impact study. A business plan is needed and should include achieving the designed capacity in a certain period of time (around 5 years) starting from the date of obtaining the license. The production capacity of the mines should be proportional to the phosphate reserves allocated for the investor in the license. Giant phosphate deposits, such as those of Swab, Marbat and Dwaima, should be divided into sectors of about 500 – 700 million tons each and each sector should be announced separately for investment. The business plan should state the production capacity of phosphate fertilizers and their types, in addition to plans of making use of by-products, such as the production of fluoride compounds and extraction of U and other trace metals from phosphoric acid and waste materials. The plan should also include waste disposal policies and environmental protection measures to be adopted.

### **PHOSPHATE DEPOSITS READY FOR EXPLOITATION**

Obviously the rehabilitation of the Akashat mine and Al-Qaim fertilizer plant is a priority for the government and may be interesting for private sector investors, but here we are proposing new deposits to be exploited in industry. These are Swab and Hirri, both of which are well explored and their reserves are accurately estimated with high degree of confidence together with detailed petrological, mineralogical, geochemical and engineering studies that allow accurate assessment and confident foundation for investors to prepare offers and business plans.



Swab deposit is very similar to Akashat deposit and both represent one industrial bed separated by wadi erosion. The deposit should be divided into 5 – 6 sectors and each sector is to be dealt with separately. The SW part of the deposit is with higher  $P_2O_5$  grade and lower stripping ratio of  $< 3$  which makes it more favorable for mining. It is anticipated that selective mining is carried out to make use of the highly pure ( $> 50\%$  CaO) nummulitic limestone overburden of the Ratga Formation (Eocene) as a raw material for cement and/ or other industries. Strip open cast mining is feasible with a stripping ratio of  $< 5$ . Beneficiation process of the raw phosphate rocks should be the same as that of Akashat, i.e. crushing, grinding, calcination, quenching, washing and disliming. A concentrate of  $> 30\%$   $P_2O_5$  is anticipated, which is suitable to feed Iraqi fertilizer plants as well as suitable to compete as an export commodity in the international market.

The second phosphate deposit ready for exploitation is the Hirri deposit (Area-1) which is unique among the Iraqi phosphate deposits, being amenable for physical routs of beneficiation without the need for the energy-consuming calcination process. The deposit is overlying the main phosphorite bed of Swab deposit at its NE part. Hence, removing the overburden and industrial bed of the Hirri deposit is actually almost exposing the industrial phosphate bed of the Swab deposit. Both deposits (Hirri and Swab) should be considered together in that part and should be announced as a single opportunity for investment. The relatively high stripping ratio of the Swab deposit in its NE part is compensated by the presence of the Hirri deposit on top of it; hence the mining costs will be shared between the two. Laboratory tests in Iraq and semi-industrial tests in India to upgrade the Hirri phosphates by physical means of size differentiation and washing proved successful and a concentrate of  $> 30\%$   $P_2O_5$  was obtained in a pilot plant test. The work in India included testing the reactivity of the concentrate with sulfuric acid and production of phosphoric acid (Unpublished archives of the Ministry of Industry and Minerals). The Hirri deposit was the target of the Ministry of Industry and Minerals to expand the fertilizers industry in Iraq, but these plans were aborted by the Gulf war in 1991.

## **CONCLUSIONS**

The defined and indicated phosphate reserves and resources in Iraq permit wide scale expansion of the fertilizers industry in the country to satisfy local demands as well as for export of fertilizers and phosphate concentrate, both of which can boost the National economy and create new revenues apart of that generated from exporting crude oil. The mining industry in general and the phosphate mining in particular, being huge and need plenty of man power, will help in the development of remote areas in the Western Iraqi Desert, by bringing water, electricity and transport to the mining sites. The best example is Akashat which was in the middle of nowhere half a century ago, but it is a small and well served town now.

Investment in the phosphate mineral industry should be open to private sector of potential capability and experience. Regulations and legislations organizing and controlling this economic practice should be made easy, but efficient in guaranteeing integrity, transparency, application of best practices in mining and industrial processing as well as to develop the mining areas and to protect the environment and social community. Government partnership with potential private sector companies may be the best choice that ensures and protects the interests of the people and National economy.

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