SOLID STATE PHYSICS, MINERAL PROCESSING

T. Tahri[1],
A. Bouzenzana[1], Dr. Sc. (Tech.),
N. Bezzi[2], Dr. Sc. (Tech.), Prof.

1 — Larbi Tebessi University, Tebessa, Algeria, e-mail: tahri2008@yahoo.fr
2 — University of Bejaia, Bejaia, Algeria

CHARACTERIZATION AND HOMOGENIZATION OF BLED EL-HADBA PHOSPHATE ORE, CASE OF DJEBEL ONK (ALGERIA)

Purpose. The aim of this study is the characterization and the development of an efficient and profitable technology for the production of one or several types of concentrates with a minimum of penalizing elements which must be competitive at the national and international levels.

Methodology. The completion of this study required the use of several methods of chemical analysis, advanced ICP-MS, SEM and XRD for defining phosphate mesh elements and gangue minerals present in the raw material, basic chemical composition and microelements (trace elements), as well as their distribution by fractions.

Findings. These studies have revealed that phosphate elements play a significant role within the main sub-layer (ML) which is situated between two other sub-layers (upper (UL) and lower (LL)). We obtained significant differences in the particle shapes and sizes, especially in the two sub-layers (UL and LL). A close relation between trace elements and various minerals (apatite, dolomite and silicates is evidenced through operations of substitution.

Originality. The research data has testified that phosphate elements play a significant role within main sub-layer (ML) which is situated between two other sub-layers (upper (UL) and lower (LL)). We obtained significant differences in the particle shapes and size, especially in the two sub-layers (UL and LL).

Practical value. The homogenization of raw materials (UL, ML and LL) developed in the laboratory has led to satisfactory results, because it presents a very wide range of variants while the poor ores of the UL and LL layers can be exploited in the amount up to 20 % each minimizing the rates of mining wastes.

Keywords: *phosphate, electron microscopy, X-ray inspection, ore homogenization, Djebel Onk deposit*

Introduction. Algeria is a country rich in various useful substances the majority of which is not developed yet. Algerian basement contains mineral resources and useful substances such as iron, lead, zinc, copper, sulphates and phosphates.

Djebel Onk is the largest phosphate deposit in Algeria, with about 2 billion tons of phosphates; its district belongs to the Gafsa-Metlaoui-Onk basin, [1] and phosphorite mineralization is distributed into five sectors: Kef Essennoun, Djemi Djema, Bled El Hadba, Northern Djebel Onk and Oued Betita.

Bled El-Hadba is taken as an example and was sampled for this study. The lithologies of Djebel Onk region are composed of a succession of about 500 m thick sedimentary layers that were deposited during the Upper Cretaceous (Maastrichtian) to Middle Eocene (Lutetian). The latter is partly covered by Quaternary continental clastic sediments (sandstones and clays). The geological and gitological contexts of the Bled El-Hadba deposit are similar to those of the area of Djemi Djema and Kef Es Sennoun, which are on the opposite side of the synclinal megastructure [1]. It is characterized by a thick layer (~ 30 m) of Upper Thanetian phosphorites which is, itself, divided into 3 sub-layers known in all Djebel Onk district based on the P_2O_5 and MgO contents [2], and tends to thicken even more towards the western limits of the deposit. However, this configuration is slightly disturbed in places, where the power of the series is relatively small.

The three sub-layers of upper Thanetian include the Upper and lower sub-layers, which are thicknesses that vary respectively between 2.30 to 18.00 m and 2.40 to 18.00 m rich in calcaro-dolomitic cement; they have low levels of P_2O_5 and a very high content of MgO.

The main layer (ML) is the largest in thickness (20 to 25 m) and in ore quality, characterized by very high levels of P_2O_5 and poor in MgO.

The overall geological reserves of the deposit are estimated at about 889,171,946.99 tons divided into 3 sub-layers: the Upper layer (UL) contains 102 858 948.61 tons, while the lower layer (LL) has reserves of 115 478 700.76 tons. The main (ML) layer contains 367 401 446.55 tons.

The present study was first proposed by Ferphos, the national Algerian company, to improve the development of a new process in this potential deposit for fur-

ther exploitation purposes and for the evaluation of economical extraction.

Phosphate ore deposits containing a high amount of carbonates and important chemical substitutions, respectively in the gangue and throughout the ore, can hardly be concentrated in phosphate elements [2].

In general, phosphor is found to be deficient in acid and calcareous soils due to the presence of high concentration of iron (Fe) or aluminium (Al) and calcium (Ca), respectively [3]. Knowing that the phosphate fertilizer industry and phosphoric acid which absorbs more than 90 % of the production of concentrated phosphate imposes quality requirements of the raw material. These requirements are related to the nature of the impurities [4] in the ore and the importance of their impact on the manufacturing process of fertilizers [5, 6]. The main quality parameters of these minerals are defined mainly by the major (P_2O_5, MgO, ...) and trace (Cr, Sr, U, ...) element contents of the ore [2]. Indeed, exceeding the normal threshold, these elements become toxic and adversely affect the quality of phosphates [4]. These can then persist in the phosphate fertilizers and, thus, agricultural food production.

The main required aim in this article is to evaluate qualitatively and quantitatively the existing major and trace elements according to granulometry, mineralogy with their repercussions on the various sub-layers to improve the quality of its products for exploitation and valorisation of the phosphate layers which depends to a large degree on the close association of minerals, on their textures, their nature and their reserves.

Materials and Methods. *Characterisation studies.* Six phosphorite samples were collected from the three sub-layers deposit of Bled El-Hadba.

Three Samples were taken from the different phosphorite layers as well. It is noted that the sampling was done systematically from top to bottom in order to follow the vertical evolution and cover the different types of facies encountered (clay, carbonate and siliceous) [1]. The petrography was studied by the examination of thin sections under a microscope using both transmitted and reflected lights.

The other three samples were taken from two upper bed trenches from each sub-layers of deposit (UL, ML and LL). These were provided by the operating company of iron and phosphate (FERPHOS).

The sampled phosphate beds from Bled El-Hadba were clearly identifiable based on the following observations (DMT):

1. The upper phosphate bed (UL, 5 m) is beige in color, very hard, with relatively coarse grains and colored.

2. The intermediate phosphate bed (ML, 11 m) is brown, fine-grained and friable.

3. The lower phosphate bed (LL, 2.5 m) is beige and hard. It had intercalations of white marl with a thickness of up to 20 cm.

The samples from each bed were dumped on the flat ground above the open pit and crushed to some extent by the shovel of the loader. The dumped piles were subjected to a mechanical treatment which consisted of homogenization, crushing and quartering operations in order to obtain a better representatively and to reduce the dimensions of the grains.

This samples prepared in the same way were the subject of an X-ray diffraction analysis in the laboratory material technologies and process engineering (LTMGP) at the University of Bejaia (Algeria) using a powder diffractometer branded "X' Pert Prof Type Panalytical MPD/ vertical system θ/θ PDS pass 4 × Accelerator (detector) platforms (Bracket) (sample-stage)" with Cu radiation with a wavelength λ = 1.5405980 Å at 2θ values between 10 and 100°.

The SEM scanning electron microscope used in our case is of S440 type from LEICA with tungsten filament composed of an electron column, a vacuum circuit and the electronic part.

500 g of a representative sample was subjected to sieve analysis using a sieving device of FRITSCH AS 200 type. It was equipped with a series of SAULAS sieves (0−4mm). The sieving time was set at 30 minutes.

Grinding (< 90 μm) was carried out on a FRITSCH, RM200 jaw crusher, grinding time was 10 to 15 minutes.

The analyses of elements major were carried out by the Algerian phosphate company (FERPHOS) using the following analytical methods: spectrophotometrically by TECHNICONAUTO ANALYZER, flame spectrophotometer, atomic absorption spectrometry (AAS) and calcimetry.

The analysis of trace elements was carried out at the Institute of Chemical Sciences of the University of Rennes 1, France using a mass spectrometer coupled to an argon plasma ICP-MS.

Preparation of samples. The thin sections were made by the first three samples, at the level of the thin section workshop of the Department of Geology, Annaba University for observation in microscope.

Sampling and analyses were carried out on the three sub-layers (upper (UL), main (ML) and lower (LL)), where 20 kg of raw phosphate was collected from each sub-layer. The mechanical preparation consisted of a series of operations: homogenization, crushing and quartering. The final representative sample weights varied between 2 to 1.5 kg. Thus, four samples representing the fractions: 0−2000; < 100; 100−315; 315−1000 and > 1000 were obtained respectively. Each grain size fraction was then finely ground using a mortar (< 90 % passing through an 80 μm sieve) for chemical and Mineralogical analysis.

Experimental procedure. In this work, we used several methods of preconditioned analyses to define the optimal meshes of release of the phosphatic elements and gangue minerals, identify the raw material mineralogical phases, the major elements chemical composition, their distribution into particle-size classes for each layer before exploitation and valorisation of this type of phosphate deposit ore.

Results and Discussion. *Chemical analysis and X-ray Diffraction analysis.* The mineralogical study carried out by the XRD revealed that apatite is a strongly substituted francolite, in OH (hydroxyapatite) and in ions F (fluorapatite).

Except in the dolomite, the presence of quartz, calcite and gypsum is not significant. All in all, the inten-

sity of the peaks is characteristic of the phosphatic elements and those of the gangue.

The results are reported in Fig. 1. They show the presence of fluorapatite, hydroxylapatite and dolomite as principal minerals. Quartz, calcite and gypsum are, however, in small amounts.

These results reveal significant differences for the three phosphate sub-layers. Indeed, the ore of the main layer is the richest in fluoroapatite, Hydroxylapatite (1) and the poorest in calcite (*a*) compared to the other two layers. However, the lower layer is the poorest in phosphate minerals and richest in dolomite (*b*) compared to the upper and main layers. Marked gypsum (*d*) occurrence is in the upper and lower layers. Quartz (*c*) is more abundant in the upper layer compared to the main and lower layers. Identification of the mineralogical composition and amount of each mineral in the different phosphate layers may suggest the most appropriate ore treatment.

Petrography compositions. The ores of Djebel Onk are grained sandy phosphates, on petrographic basis; the ores are classified as phospharenite; the phosphatic facies are homogenous, with fine grains (200 to 300 μm),

rarely heterogeneous with both fine grains and coarse grains (up to 3 mm). Phosphate particles involve pellets, coprolites and bioclasts (bones, teeth of fishes and cellular bone fragments). The phosphorite particles are cemented by either argillaceous (soft phosphorites) or carbonaceous (hard phosphorites) matrix [7].

The microscopic SEM and microscopic optical observations (Figs. 2, 3 and 4) highlight the presence of the principal minerals identified by XRD (Fig. 1).

The phosphate of the upper sub-layer (UL) in Fig. 2, *B* is characterized by the heterogeneity of the grains: glouconite (G), bone debris (D), with the abundance of coprolite (CO), thes grains are bound by cement (60 %) dolomitic and clacitique (hard ore). This layer (UL) is very rich in glauconite and some quartz (Q) grain compared to the tow sub-layers (ML and LL); it can be consistent with sedimentary levels of Maastrichtian [8].

The phosphatic facies of the main sub-layer (ML) are homogenous compared to the two sub-layers, the upper (UL) and lower (LL).

The phosphate of the main layer is generally composed of oolites (O) and pellets with the presence of
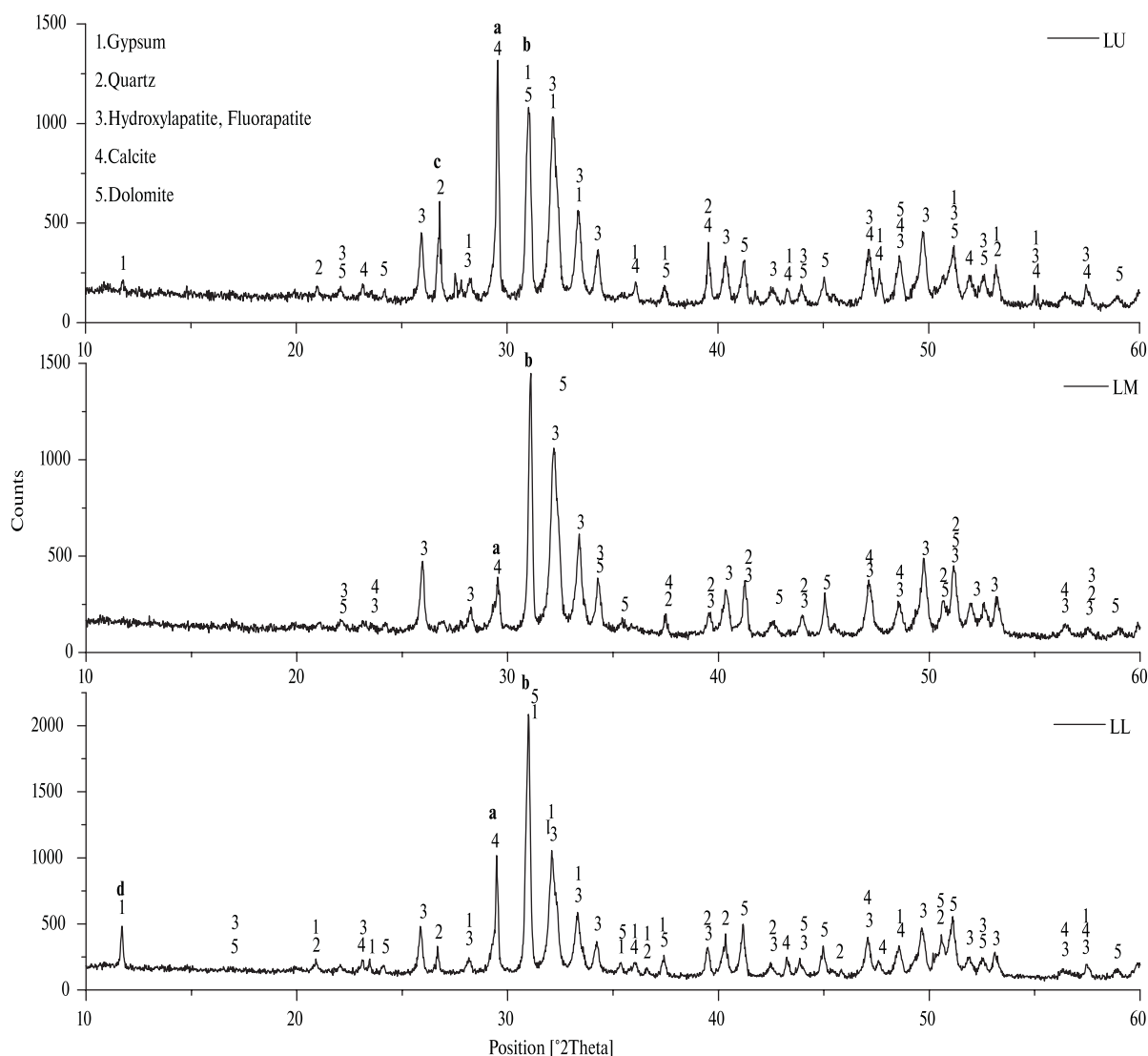

Fig. 1. XRDs of the series of raw samples from the three sub-layers (upper, main and lower)
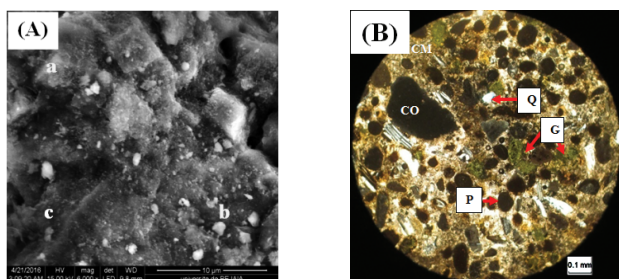
Fig. 2. Petrographic analysis of phosphate sample from the upper layer (UL):

A − SEM microphotographs of phosphate sample from the upper layer (UL); B − microphotography in polarized-light analyzed of phosphate sample from the upper layer (UL); a − mixture of phosphate crystals; b − silica; c − phosphate elements
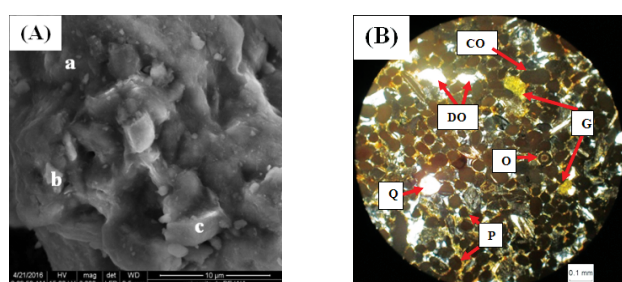

Fig. 3. Petrographic analysis of phosphate sample from the main layer (ML):

A − SEM microphotographs of phosphate sample from the main layer (ML); B − microphotography in polarized-light analyzed of phosphate sample from the main layer (ML); a − mixture of phosphate crystals; b − potassium feldspar; c − clay mineral
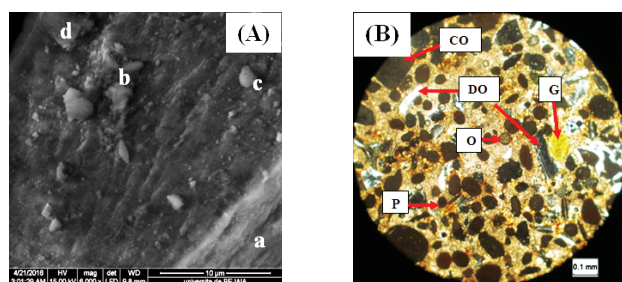

Fig. 4. Petrographic analysis of phosphate sample from the lower layer (LL):

A − SEM microphotographs of phosphate sample from the lower layer (LL); B − microphotography in polarized-light analyzed of phosphate sample from the lower layer (LL); a − phosphate elements; b − dolomite; c − silica d − phosphate elements associated with quartz

some small coprolites (CO), bone debris (DO), glauconite (G) and quartz (Q). This grains are bound by a micritic cement (15 %) of clay natural (friable soft ore); however, it can also be carbonated, Fig. 3, *B*.

The phosphate of the sub-law layer shown in Fig. 4, *A* is characterized by the abundance of cement (75 %) dolomitic and sometimes calcitic, with the presence of some heterogeneous grains: big size coprolites (CO), bone de-

bris (D), glauconite (G), pellets (P) and quartz (Q) small grains. This difference between the three sub-layers may be due to their distinct sedimentary and paleogeographic parameters which condition the quality of the ore [9].

The microscopic observations made on these three types of ore showed the presence of the principal minerals: fluorapatite, hydroxylapatite, carbonate, dolomite, calcite, quartz, feldspar and clays.

Chemical compositions. Chemical analyses of major elements (P_2O_5, MgO, CaO, SiO_2, Al_2O_3, Fe_2O_3, TiO_2, Na_2O, K_2O; loss on ignition, and others) were carried out on whole rock samples and the results are shown in Table 1. The contents of these elements (in weight per cent) are distributed on the major mineral phases of the rock. The principal quality parameters of these ores are mainly based on the contents of major elements (P_2O_5, MgO, ...) and existing trace elements (Cr, Sr, U, ...) [2].

The chemical element contents show differences between the three phosphates sub-layers considered in this study.

1. The main sub-layer (ML) ore is richer in CaO and P_2O_5 than the other two sub-layers.

2. The upper (UL) and lower (LL) sub-layers show slightly higher contents of MgO, loss on ignition (LOI), and CO_2 than those in the main sub-layer (ML).

3. The lower sub-layer (LL) ore is richer in silica (SiO_2), iron oxide (Fe_2O_3) and lower in soda (Na_2O) compared to the other two layers.

Djebel Onk phosphate rock has a high substitution of CO_3 (CaO/P_2O_5 = 1.75−1.90) and generally is low in silica and in iron [10]. The CaO/P_2O_5 (2.04 and 2.09 %) ratio is higher in the case of the UL and LL; this reflects the importance of well-developed dolomitic carbonate cement [2]. The results show that the main sub-layer is indeed richer in P_2O_5 and poorer in MgO, SiO_2, and CO_2 than the upper and lower sub-layers.

The variation observed for the (UL, ML and LL) sub-layers is, primarily related to the size, shape and structure of the grain, the mineralogical and chemical composition.

Table 1

Major element analyses of the different phosphate sub-layers (UL, ML and LL)

Major elements	Contents, %		
	UL	ML	LL
P_2O_5	21.68	27.07	20.03
CaO	44.30	48.50	42.06
LOI	16.10	13.30	18.07
CO_2	14.48	10.20	15.78
SiO_2	08.10	05.90	06.70
MgO	03.51	02.72	04.91
Na_2O	00.57	00.93	00.83
Fe_2O_3	00.52	00.49	00.46
K_2O	00.02	00.01	00.02

The principal quality parameters of these ores are mainly based on the contents of major elements (P_2O_5, MgO, ...) and existing trace elements (Cr, Sr, U, ...) [2].

The chemical analyses of trace elements were carried out for the three samples (UL, ML and LL) in a finely crushed state (<80 μm). The results of the analyses obtained for the three samples (Table 2) highlight the presence of about fifteen trace elements made up in majority of transition metals (vanadium, chrome, cobalt, copper, nickel, zinc, lead and ytterbium) and some elements of promethium (lanthanum, cerium, neodymium and erbium). However, one element of the alkaline-earth metals (strontium), alkaline metals (cesium) and actinides family (uranium) are also identified.

The results show the presence of fifteen trace elements that are divided into 5 categories:

1. Transition metals: vanadium, chromium, copper, nickel and zinc.

2. Rare earths: lanthanum, yttrium, cerium, neodymium and erbium.

3. Alkaline earth metals: strontium.

4. Alkaline: cesium.

5. Actinide: uranium.

According to the chemical composition of such elements, we distinguish three main groups:

Group 1, comprising average contents of trace elements (10 to 50 ppm), and composed of actinides, metals of transition and lanthanides: lead (Pb), uranium (U), copper (Cu) vanadium (V), chromium (Cr), cadmium (Cd) and nickel (Ni) of the upper sub-layer (UL) but the main sub-layer (ML) contains all these elements with lanthanum (La) except for vanadium (V) and the lower sub-layer (LL) contains all the elements of (ML) with cesium (Cs) except for cadmium (Cd).

Table 2

Chemical analysis of trace elements in the raw ore of the three sub layers (UL, ML and LL)

Trace elements	Contents, ppm		
	UL	ML	LL
Pb	10	20	13
Cu	25	30	60
Ni	20	25	18
U	35	40	30
V	41	63	55
Cd	35	10	75
Cr	15	12	17
Cs	71	55	38
Zn	49	88	79
Sr	150	357	288
La	59	41	38
Y	78	67	69
Ce	58	76	87
Nd	99	55	58
Er	63	69	74

Group 2, comprising average contents of trace elements (50 to 100 ppm), and composed of transition metals and lanthanides: chromium (Cr), zinc (Zn), yttrium (Y), lanthanum (La), cerium (Ce), erbium (Er), cesium (Cs) and neodymium (Nd) of the upper sub-layer (UL) but the main sub-layer (ML) contains all these elements with vanadium (V) except for lanthanum (La) and the sub-layer (LL) contains all the elements of (ML) with cesium (Cs) except for cadmium (Cd) and the lower sub-layer (LL) contains all the elements of (ML) with cadmium (Cd) except for cesium (Cs).

Group 3, comprising strong contents of trace elements (>100 ppm), and composed also cerium (Ce) of the three sub-layer (UL, ML and LL).

The trace element contents, such as Cd, U, As and Sr, observed in whole-rocks of Bled El Hadba, are generally low and meet the standards required by the phosphate industry. Unlike cadmium, the evolution of uranium and strontium depends on the phosphate content. The binding of these elements in the apatitic structure is of diverse origin [11]. Cadmium is bound much more to the clay phase (thin slice) than to apatite. The substitution of uranium in the apatitic structure is highly probable because of the very close ionic of Ca^{2+} and U^{4+} ions. On the other hand, the substitution of strontium in apatite is adverse due to the difference of the ionic rays of Ca^{2+} and Sr^{2+}. Thus, the origin of this element is attributed in part to its adsorption on the surface of apatite crystals. The variation observed for the UL, ML and LL series is, primarily related to the smoothness of the grains, the chemical and mineralogical composition.

Bled el Hadba phosphate ore rich in rare earth especially cerium may be due to the abundance of Glauconite where, in the two deposits (Kef Essenoun and Djebel El Kouif), the glauconite grains are richer in ETR than the other coexisting particles (pellets, coprolites, enamel and dentine of marine fish teeth) [12].

Grinding process and particle-size analysis. The Grain-size classification of the raw phosphate obtained after mechanical treatment and sieving for the three samples (upper (UL), main (ML) and lower (LL) layers) are reported in Fig. 5 and Table 3, which show major element (P_2O_5, CO_2 and MgO) contents versus phosphate grain-size for the three sub-layers. The phosphate grain size is represented mainly in the size frac-
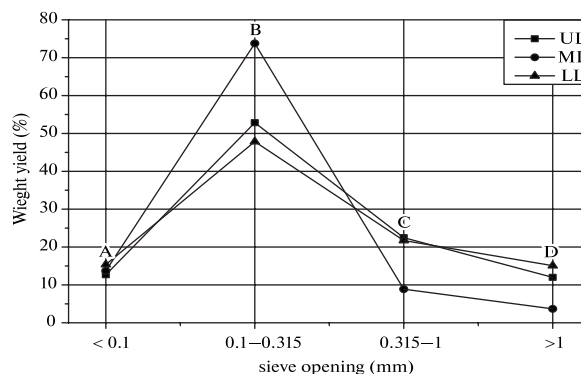

Fig. 5. Sample weight (%) versus size particle size classes of the three samples (UL, ML and LL)

Major element (P_2O_5, CO_2 and MgO) contents versus sample size classes (LL, ML and LL)

Fraction (mm)	Yield, %			P_2O_5, %			MgO, %			CO_2, %		
	UL	**ML**	**LL**	**UL**	**ML**	**LL**	**UL**	**ML**	**LL**	**UL**	**ML**	**LL**
Overall	100	100	100	**21.68**	**27.07**	**20.03**	2.99	2.10	3.65	12.36	09.64	13.23
>1	11.99	03.64	15.08	13,62	19.49	12.34	5.01	4.24	6.54	22.68	17.43	22.03
0.315−1	22.48	08.86	21,72	20.12	23.84	20.10	3.55	2.62	3.59	12.88	12.66	13.48
0.1−0.315	**52.84**	**73.77**	**47.83**	**27.30**	**30.48**	**27.12**	**1.38**	**1.00**	**1.69**	**07.40**	**06.58**	**07.56**
<0.1	12.69	13.72	15.37	10.10	12.80	10.20	6.8	7.13	7.00	22.36	22.03	21.87

tions between (0.1−0.315 mm) and (0.315−1 mm), with respective percentages of 75.32, 82.61 and 69.55 % for the upper (UL, ML and LL).

Fine fractions (<0.1 mm) are gangue elements recorded at 12.69, 13.72 and 15.37 % for the UL, ML and LL sub-layers, respectively.

The fine fractions are rich in siliceous, dolomitic and argillaceous materials. Coarse fractions (>1 mm) are also predominantly gangue elements with 11.99, 03.67 and 15.08 % for the UL, ML and LL sub-layers, respectively.

It is worth noting that the weight is higher in the intermediate fraction (0.1−0.315 mm) for the main layer (ML) compared to that of the upper (UL) and lower layers (LL). This is attributed to the abundance of phosphate elements in the fine fraction of top, 0.1 mm. However, the weight (A) is higher in the two sub-layers because it contains finer (siliceous) particles than the main sub-layer (ML).

From a chemical point of view, the best contents in phosphate (P_2O_5) and in elements of the gangue (MgO and CO_2) are located within the beneficiation range of 100 to 315 μm, where the mesh of release of the phosphatic elements is also located.

The reduction in the frequency in these elements results in strong contents of MgO and CO_2 which are reflected on P_2O_5 outputs [2].

Homogenization collective and selective. The different analysis techniques applied to these types of minerals have shown a close relationship between the petrographic and mineralogical phases and between the particle size distribution and evolution of chemical contents and, on the other hand, developed a method for homogenization of the three sub-layers which offers a wide va-

riety of mixes that can meet the exploitability criteria. It allows a new approach in the exploitation and the valorization of the ore aiming to provide a phosphate concentrate of better quality; optimal management of raw materials and minimization of the rate of sterile releases. In this study, we preposition a collective homogenization (TL) according to the percentage of reserves representing all the deposit and selective homogenization (ML and UL with LL (LU)) according to the quality from each sub-layer. Grain-size classification of the raw phosphate obtained after homogenization and treatment and sieving for the three samples (TL, ML and LU) are reported in Table 4 and Fig. 6, respectively showing the major element (P_2O_5, CO_2 and MgO) contents versus phosphate grain-size for the three news qualities.
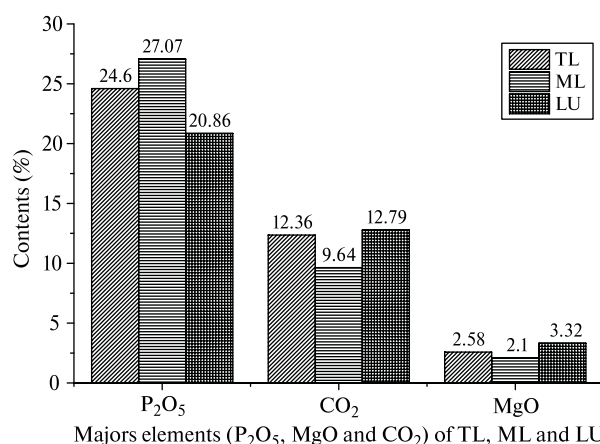

Fig. 6. Major element (P_2O_5, CO_2 and MgO) contents versus samples (TL, ML and LU)

Major element (P_2O_5, CO_2 and MgO) contents versus sample size classes (TL, ML and LU)

Fraction (mm)	Yield, %			P_2O_5, %			MgO, %			CO_2, %		
	TL	**ML**	**LU**	**TL**	**ML**	**LU**	**TL**	**ML**	**LU**	**TL**	**ML**	**LU**
Overall	100	100	100	**24.60**	**27.07**	**20.86**	2.58	2.10	3.32	12.36	09.64	12.79
>1	07.57	03.64	13.52	16.90	19.49	12.98	4.85	4.24	5.77	22.68	17.43	22.36
0.315 -1	14.13	08.86	22.10	22.35	23.84	20.11	2.99	2.62	3.57	12.88	12.66	13.18
0.1−0.315	**64.45**	**73.77**	**50.35**	**29.18**	**30.48**	**27.21**	**1.21**	**1.00**	**1.53**	**07.40**	**06.58**	**7.48**
<0.1	13.84	13.72	14.02	11.74	12.80	10.15	7.04	7.13	6.89	22.36	22.03	22.12

After the homogenization collective of the three sub-layers, we obtain a product (TL) which represents all the deposit with a top quality 53TPL. Than the selective homogenization produced two qualities: ML, higher than 59TPL and LU, higher than 45TPL.

Conclusion. The characterization work carried out on Bled El Hadba raw phosphate allowed us to define the optimal meshes for the release of the phosphate elements: the microscopic observations made on these three types of ore showed the presence of the principal minerals: fluorapatite, hydroxylapatite, carbonate, dolomite, calcite, quartz, feldspar and clays.

1. The variation observed for the (UL, ML and LL) series is primarily related to the size, shape and structure of the grain, the mineralogical and chemical composition.

2. The mineralogical study carried out by the XRD revealed that apatite is a strongly substituted in OH (hydroxyapatite) and in ions F (fluorapatite). Except for the dolomite in samples raw, the presence of quartz, calcite and gypsum is not significant.

3. From granulometric point of view, the size classification carried out by sieving revealed that the bulk of the total mass of the raw ores is represented by the size range $0.100 - 0.315$ mm and constitutes the mesh of optimal release of the separation of the phosphatic (52.48, 73.77 and 47.83 %); recorded weights yield very important for the three sub-layer (UL, ML and LL) rich in phosphates P_2O_5 (27.12, 30.48 and 27.12 % respectively).

4. From a chemical point of view, the ML layer differs from the UL and LL only through the high frequency of (P_2O_5) and a clear decrease in the amount of (MgO) and (CO_2).

5. The chemical analyses carried out on the raw ore highlighted the presence of two groups of quite distinct elements by their intensities: major elements (phosphorus, calcium, magnesium and silicon) and trace elements (vanadium, chrome, cobalt, copper, nickel, zinc, lead, ytterbium, lanthanum, cerium, neodymium, erbium, strontium, cesium, uranium).

Therefore, we propose a selective and collective exploitation and treatment method for the three sub-layers (UL ML and LL) for the production of one or several types of concentrates with minimum disadvantageous elements that must be competitive on the national and international level.

References.
1. Rabah, K., Rabah, L., Olivier, B., Sihem Laouar, S., Ouafi, A. and Atif, F., 2016. Preliminary data of REE in Algerian phosphorites: a comparative study and paleoredox insights. *Procedia Engineering*, 138, pp. 19−29.
2. Bezzi, N., Aïfa, T., Hamoudi, S. and Merabet, D., 2012. Trace elements of Kef Es Sennoun natural Phosphate (Djebel Onk, Algeria) and how they affect the various Mineralurgic modes of treatment. *Procedia Engineering*, 42, pp. 1915−1927. DOI: 10.1016/j.proeng.2012.07.588.
3. Sarkar, A., Biswas, D.R., Datta, S.C., Manjaiah, K.M. and Roy, T., 2017. Release of Phosphorus from Laboratory Made Coated Phosphatic Fertilizers in Soil Under Different Temperature and Moisture Regimes. In: *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, 87(4), pp. 1299−1308. DOI: 10.1007/s40011-015-0693-8.
4. Lassis, M., Mizane, A., Dadda, N. and Rehamnia, R., 2015. Dissolution of Djebel Onk phosphate ore using sulfuric acid. *Monitoring & Management Environmental Nanotechnology*, 4, pp. 12−16.
5. Sinirkaya, M., Ozer, A. K. and Gulaboglu, M. S., 2014. Investigation of the solubilities of sulfated and ground phosphate rock after sulfation in H_2SO_4 solution. *Journal of engineering sciences*, 20, pp. 253−257.
6. Bouzenzana, A., 2013. Harmful elements in concentrates them of phosphate and method of disposal case of "Jebel-Onk" Algeria. *Journal of ore dressing*, 15, pp. 25−30.
7. Dass-Amiour, M., Mezghache, H. and Elouadi, B., 2011. The use of three physico-chemical methods in the study of the organic matter associated with the sedimentary phosphorites in Djebel Onk Basin, Algeria. *Arabian Journal of Geosciences*, 2, pp. 1866−7511. DOI: 10.1007/s12517-011-0381-9.
8. El Haddia, H., Benbouzianea, A., Moufliha, M., Jouranib, E. and Amaghzaz, M., 2014. Siliceous forms of phosphate deposits of Cretaceous age in Oulad Abdoun basin (Central Morocco). Mineralogy, geochemistry and diagenetic phenomena. *Procedia Engineering*, 83, pp. 60−69.
9. Priana, J. P., 2014. Phosphate deposits of the Senegal-Mauritania-Guinea Basin (West Africa): A review. *Procedia Engineering*, 83, pp. 27−36.
10. Mizane, A. and Rehamnia, R., 2012. Study of some parameters to obtain the P_2O_5 water-soluble from partially acidulated phosphate rocks (PAPRs) by sulfuric acid. *Phosphorus Research Bulletin*, 27, pp. 18−22. DOI: 10.5923/j.re.20120204.07.
11. Kocsis, L., Gheerbrant, E., Mouflih, M., Cappetta, H., Ulianov, A., Chiaradia, M. and Bardet, N., 2016. Gradual changes in upwelled seawater conditions (redox, pH) from the late Cretaceous through early Paleogene at the northwest coast of Africa: Negative Ce anomaly trend recorded in fossil bio-apatite. *Chemical Geology*, 421, pp. 44−54.
12. Kechiched, R., Laouar, R., Bruguier, O., Salmi-Laouar, S., Kocsis, L., Bosch, D., Foufou, A., Ameur-Zaimeche, O. and Larit, H., 2018. Glauconite-bearing sedimentary phosphorites from the Tébessa region (eastern Algeria): Evidence of REE enrichment and geochemical constraints on their origin. *Journal of African Earth Sciences*, 145, pp. 190−200.

Визначення характеристик і гомогенізація фосфатної руди Блед Ель-Хадба на прикладі родовища Джебель Онк (Алжир)

Т. Тахрі[1], *А. Бузензана*[1], *Н. Беззі*[2]

1 — Університет Ларбі Тебессі, м. Тебесса, Алжир, e-mail: tahri2008@yahoo.fr
2 — Університет Беджая, м. Беджая, Алжир

Мета. Розробка ефективної та прибуткової технологія для виробництва одного або декількох продуктів збагачення руди з найменшою кількістю елементів, що викликають брак, які повинні бути конкурентоспроможними на національному й міжнародному рівнях.

Методика. Виконання даного дослідження вимагало застосування декількох методів хімічного аналізу, удосконаленої мас-спектрометрії з індукційною плазмою (МСІМ), скануючої електронної мікроскопії (СЕМ) і дифракційного рентгенівського аналізу (ДРА) для виявлення меш-елементів фосфату й порожньої породи, присутніх у сировині, основного хімічного складу й мікроелементів (слідів елементів), а також їх розподілу між фракціями.

Результати. Дані дослідження показали, що елементи фосфату відіграють значну роль в основному підшарі (ОШ), який розташований між двома іншими підшарами (верхнім (ВШ) і нижнім (НШ)). Ми отримали значне розходження між формами й розмірами частинок, особливо у двох підшарах (ВШ і НШ). Доведено тісний зв'язок між мікроелементами та різними мінералами (апатити, доломітами й силикатами) шляхом здійснення заміщення.

Наукова новизна. Дані дослідження показали, що елементи фосфату відіграють значну роль в основному підшарі (ОШ), який розташований між двома іншими підшарами — ВШ і НШ.

Практична значімість. Гомогенізація сировини (ВШ, ОШ і НШ), розробленої в лабораторних умовах, дала задовільні результати, оскільки пропонує широкий ряд варіантів, а низькосортні руди верхнього й нижнього шарів можуть бути використані в кількості до 20 % кожен, мінімізуючи показники порожньої породи.

Ключові слова: *фосфати, електронна мікроскопія, рентгеноскопія, гомогенізація руди, родовище Джебель Онк*

Цель. Разработка эффективной и прибыльной технология для производства одного или нескольких продуктов обогащения руды с наименьшим количеством элементов, вызывающих брак, которые должны быть конкурентоспособными на национальном и международном уровнях.

Методика. Выполнение данного исследования потребовало применения нескольких методов химического анализа, усовершенствованной масс-спектрометрии с индукционной плазмой (МСИМ), сканирующей электронной микроскопии (СЭМ) и дифракционного рентгеновского анализа (ДРА) для выявления меш-элементов фосфата и пустой породы, присутствующих в сырье, основного химического состава и микроэлементов (следовых элементов), а также их распределения по фракциям.

Результаты. Данные исследования показали, что элементы фосфата играют значительную роль в основном подслое (ОС), который расположен между двумя другими подслоями (верхним (ВС) и нижним (НС)). Мы получили значительное расхождение между формами и размерами частиц, особенно в двух подслоях (ВС и НС). Доказана тесная связь между микроэлементами и различными минералами (апатитами, доломитами и силикатами) путем осуществления замещения.

Научная новизна. Данные исследования показали, что элементы фосфата играют значительную роль в основном подслое (ОС), который расположен между двумя другими подслоями — ВС и НС.

Практическая значимость. Гомогенизация сырья (ВС, ОС и НС), разработанного в лабораторных условиях, дала удовлетворительные результаты, поскольку предлагает широкий ряд вариантов, а низкосортные руды верхнего и нижнего слоев могут быть использованы в количестве до 20 % каждый, минимизируя показатели пустой породы.

Ключевые слова: *фосфаты, электронная микроскопия, рентгеноскопия, гомогенизация руды, месторождение Джебель Онк*

Определение характеристик и гомогенизация фосфатной руды Блед Эль-Хадба на примере месторождения Джебель Онк (Алжир)

Т. Тахри[1], *А. Бузензана*[1], *Н. Беззи*[2]

1 — Университет Ларби Тебесси, г. Тебесса, Алжир, e-mail: tahri2008@yahoo.fr

2 — Университет Беджая, г. Беджая, Алжир