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OCCURRENCE OF BARITE MINERALIZATION IN BAHARIYA DEPRESSION, WESTERN DESERT, EGYPT

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Barite vein mineralization has been recorded South of Gebel El Haufhuf in the ground surface of El Bahariya depression, Western Desert of Egypt. The barite veins that trend in different directions are actually associated with major fold and fault structures that are retricted to the oldest sandstone rock of the Sabaya Formation. Some of these veins attain more than 7m length and a width ranging between 0.5 and up to 4m. The discovered barite veins are exclusively composed of barite and quartz with barite attaining 56% by weight. Besides the genetic aspects of the studied mineralization, the degree of liberation have been discussed.

key words: barite mineralization, genetic aspects, liberation degree, Bahariya depression, Western Desert of Egypt

INTRODUCTION

Barite ($BaSO_4$) is the only commercial source of barium except for minor sources of witherite ($BaCO_3$), which is generally restricted to China. By virtue of its relatively high specific gravity (4.5), over 70% of barite demand is used primarily as a weighting agent in drilling muds in the oil and gas industry as well as to cap oil and gas wells. Barite for drilling purposes must be free of soluble salts, contain a minimum of 92% $BaSO_4$ and have a specific gravity of 4.2, several percent iron oxide is not objectionable and 90-95% of the ground materials must pass a -325 mesh screen. Due

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to its physical attribute and/or chemical inertness, barite is also used in construction and as functional filler in paints, plastics, rubber, printing inks and papers industries.

Barite is widely distributed in several districts of the USA (Carterville, Georgia) (Bate, 1996) and in western Ouachita mountaines, Arkansas (Mitchell, 1984). Barite deposits are also known in several other countries; namely Canada, Southern America (Peru, Argentina, Brazil, Chile and Colombia), Germany, former USSR, Italy besides Algeria, Morocco, Zimbabwe, China and Australia.

In Egypt barite is widely distributed in the North Eastern Desert such as Um Monqul area besides the veins in the pink granite at east of Aswan and at Gebel El Hudi near Aswan. Also, it occurs as sediments and veins in El Shieh El Shazly area in South Eastern Desert. Additionally, barite is present as a cementing material for sandstones in Kharga Oasis, Western Desert. Several modes of formation of barite deposits have been identified with most commercial sources belonging to replacement deposits in limestone, dolomite sandstone and shales or residual deposits in which lumps of barite are enclosed in clay caused by differential weathering. Barite sometimes occur in veins and as a gangue mineral in metallic ores such as lead, zinc and silver and is frequently associated with fluorspar.

High grade barite mineralization has actually been recorded for the first time in the Cretaceous Sabaya Formation occurring in El Bahariya Oasis, Northwestern Desert. Field investigation and mineralogical studies were carried out in order to define its characteristics and to elucidate its origin as well as its economic significance.

SAMPLING AND TECHNIQUES

A representative bulk composite sample of the defined barite veins was collected (weighing about 12 kg) from the different mineralized zones in the study area. For a proper mineralogical and chemical characterization of the discovered mineralization, a portion of the collected sample was subjected to both XRD and XRF analyses. On the other hand, for the liberation investigation, the representative bulk sample was subjected to proper crushing, grinding and sieving using screens: 0.80, 0.63, 0.40, 0.20, and 0.045mm. The obtained size fractions were subjected to heavy minerals separation using bromoform (sp. gr. = 2.85 gm/cm^3). The obtained heavy and light fractions were then microscopically examined under the binocular microscope to determine the degree of barite liberation. In addition, picked composite and pure grains were subjected to examination by the Environmental Scanning Electron Microscope (ESEM). The latter is supported by energy dispersive spectrometer unit (EDS), model Philips XL 30. The analytical conditions included 30 kV accelerating voltages, 1-2 mm beam diameter and 60-120 second counting time, and minimum detectable weight concentration from 0.1 to 1 wt%. All of the mentioned analyses were carried out at the laboratories of the Egyptian Nuclear Materials Authority (NMA).

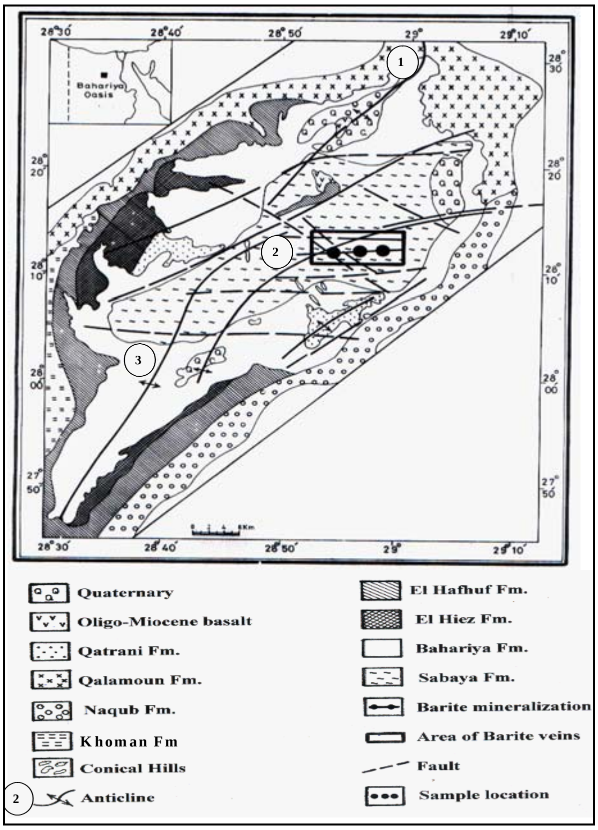

Fig.1. Geologic map of Bahariya Oasis showing barite occurrence, after Morsy (1987) with slight modification

FIELD INVESTIGATION

GENERAL STRATIGRAPHY OF THE EL BAHARIYA OASIS

The El Bahariya Oasis is an oval shaped depression (Fig. 1) trending in a NE-SW direction. Within the depression, the Cretaceous rocks outcrop at its base as well as at the base of the conical hills and the scarp. The Cretaceous rock succession (Sabaya, Bahariya, El Heiz and El Hafhuf Formations) comprises fluvialite to fluviomarine clastics of sandstone, claystone and shale. The Sabaya Formation of Lower Cenomanian age (Morsy, 1987) is coverd by Bahariya Formation which also belongs to the Lower Cenomanian (Soliman and El Badry, 1980). The Bahariya Formation is unconformably overlain by the Upper Cenomanian fluviomarine marly shale, sandy dolomitic limestone and calcareous sandstone of El Heiz Formation as well as by the Campanian cherty cavernous dolostone, crossbedded sandstone and phosphatic limestone of El Haufhuf Formation (Morsy, 1987).

The succeeding maeastrichtian Khoman Formation is mainly represented by chalk and chalkly limestone. It overlies conformably El Haufhuf Formation on both sides of the depression and extends southward with increasing thickness (Fig. 1). The Eocene rocks are represented by the Naqb Formation which belongs to the Middle Eocene (Said, 1962) and comprises gray and pink limestone and by the Qalamoun Formation which belongs to the Lower Eocene (El Shazly, 1962). The Qalamoun Formation is deposited on the Bahariya Formation and El Haufhuf Formation to the North of El Bahariya depression (Fig.1). The succeeding Oligocene Qatrani Formation (Morsy, 1987) covers El Bahariya Formation at the top of the conical hills besides occurring as small outcrops within the depression. This formation consists of quartizitic sandstone, quarzite, shale and silt.

At the northern part of Gebel El Haufhuf, Oligo-Miocene basaltic and doleritic extrusions (sheets, sills and dikes) are recorded (Morsy, 1987; Meneisy and El Kaleubi, 1975).

MODE OF OCCURRENCE OF EL BAHARIYA BARITE

High grade barite mineralization is found mainly in the form of different veins restricted to the ground surface of El Bahariya depression (Fig. 1). The barite veins trend in different directions and are actually associated with the major folds and faults that are restricted to the oldest rocks of Sabaya Formation which form the floor of the depression. In order to study the barite veins, the structure configuration of the El Bahariya Oasis depression must first be studied. The latter occurs within a major northeast trending belt of considerable extension about 100 km long and 40 km wide. Several other folds of the same or later tectonic phase but of lesser extension occur parallel to or perpendicular to the main anticlinal trend i.e. trending either NE or NW. Morsy (1987) discussed the structure of the Bahariya Oasis and concluded that more than two folding generations can be identified. The trends of these folds are chronologically arranged from the younger to the older according to the following sequence; viz, NW-SE, NE-SW and E-W.

The following is a brief description of the major fold trends restricted to the northern part of the El Bahariya Oasis.

i- Anticline No.1 is a NE trending fold. Its axis has NE-SW direction and plunges 5º due North. The length of the anticline is about 30 km.

ii- Anticline No.2 has the same NE trend of anticline No.1 and its axis plunges 4º due North. Many small to medium size synclines occur parallel to the axis of this anticline.

iii- Anticline No.3 is a major fold restricted in southern part (Fig. 1).

On the other hand, several faults of different directions and magnitudes are also observed in the El Bahariya Oasis (Fig. 1). These faults include E-W faults that dip due South with more than 30 m vertical displacement as well as NE-SW faults that dip to the north or south and extend for a length reaching 100 km with 10-40 m vertical displacement.

The discovered barite mineralization veins are hosted in the sandstone beds of the Sabaya Formation. This Formation is composed of channel sediments of tabular cross-stratification, medium to coarse grained sandstone and of flood plain deposits of clayey sandstone (Fig. 2A).

The lithological features suggest the sandstone beds were deposited in a fluviatile environment. The barite veins are widely distributed to the south of Gebel El Hafhuf which is composed of a rock sequence including sandstone, shale, limestone, phosphatic limestone and phosphatic calcareous sandstone. This succession is capped by the Oligo-Miocene basaltic sheet which takes the form of open circle of about 20 m thickness (Fig. 2B).

The barite veins are restricted to the fractures that are parallel to the main E-W or NW-SE striking faults in the Sabaya Formation (Fig. 1). These veins occur subparallel sets with more than 7 m length and ranging in width between 0.5 to 4 m. They dip 50º towards N, S or NE directions. The barite veins are hard, massive, siliceous and white to gray in color (Fig. 2C). These veins are numerous and distributed in association with tectonically formed fractures and fissures.

GENETIC ASPECTS OF EL BAHARIYA BARITE MINERALIZATION

From the field investigation and the geologic setting of the barite veins host rocks, it has been possible to elucidate the origin of the studied barite mineralization. Accordingly, the following genetic model and succession has been proposed:

i- The Cretaceous shallow marine to fluvial siliciclastic strata have been first deformed by both folding and faulting.

ii- Barium was leached from the basaltic extrusion during high temperature circulation (Von Damn et al, 1985). Tertiary Oligocene basalt at Gebel El Haufhuf, Bahariya Oasis is related to continental intraplate volcanism, which is contiemporaneous with the opining of the red sea and uplift of Afro-arabian mountain. Fumarolic and geyser activities belong to Oligocene period were consider as gas maar resulting from a phreatic explosion (El-Kammar, 2000).

iii- Release of sulphate fluids from the sulphate-rich minerals involved in the Brine deposits distributed within El Bahariya Depression at the Qaternary (Haroun, 1990) ; namely polyhalite, kieserite and kyanite.

iv- Migration of these fluids through the deformed strata followed by barite mineralization as a result of a rapid primary precipitation at or above the sediment / fluid interfaces.

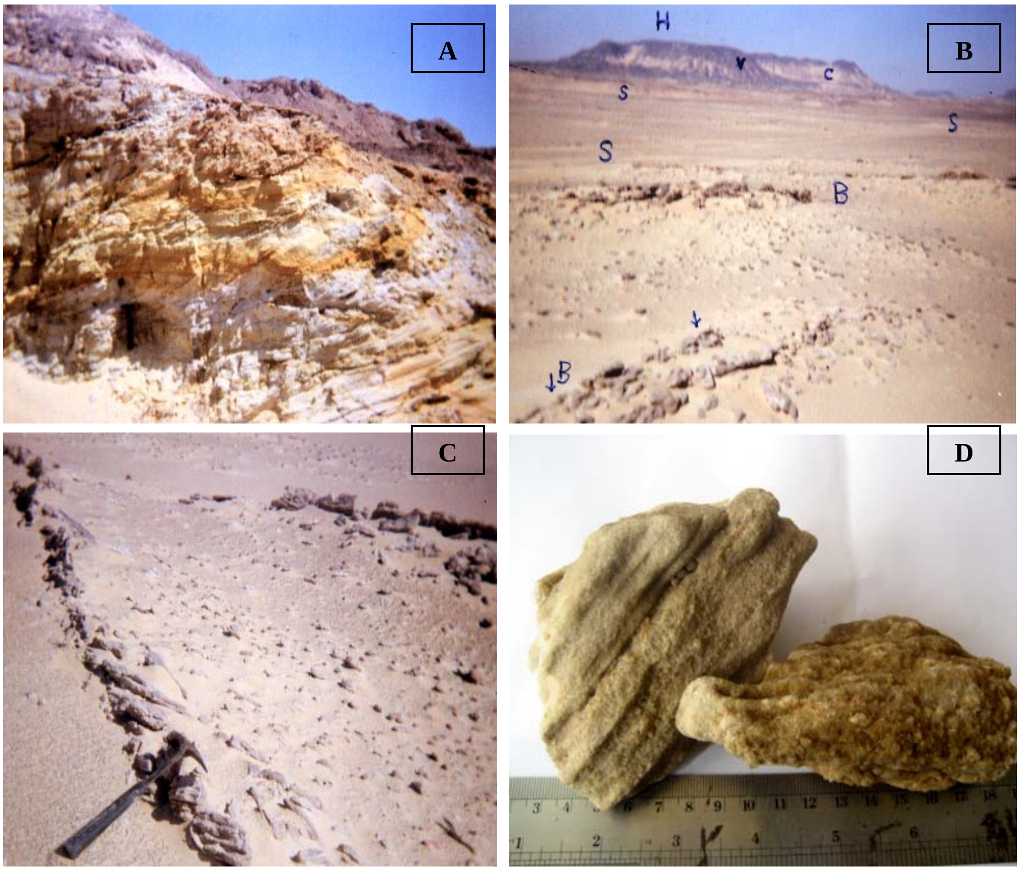

Fig. 2.
A- Outcrop of Sabaya sandstone (Lower Createaceous) hosting barite mineralization. Crossbedded sandstone represent the channel deposits of fluvial environment. B- Photograph showing the area of barite veins. Subparallel barite veins (B) are hosted in sandstone of the Sabaya Formation (S). Barite mineralization restricted south Gebel El Hafhuf (H) which is composed of Createaceous rocks (Campanian) (C) caped by Oligomiocene Basaltic sheets (V). Barite veins trending NE-SW. Looking North West. C- Closed up view of barite vein dipping 50 toward NW direction with length more than 7 m. (Hammar = 20 cm).D- Closed up view of barite samples characterized by well developed quartz granules. Barite occur as aggregates and tabular forms with white to grey coloration.

MINERALOGICAL AND LIBERATION CHARACTERISTICS

MINERALOGICAL INVESTIGATION

As mentioned above, the collected samples of the barite -bearing veins are hard, compact, heavy and siliceous. The barite veins are almost exclusively composed of barite cementing quartz sand grains. The barite mineral itself occurs as aggregates of tabular form crystals and is characterized by a white to grey coloration**.** The sand grains in the veins are of coarser grain size and are ill sorted indicating a low degree of maturity (Fig. 2 D).

Table 1. XRD pattern for barite veins bulk sample

Sample		Barite ASTM 5-0448		Quartz ASTM 5-0490	
dA°	I/I_0	dA°	I/I_0	dA°	I/I_0
4.44	5	4.44	17		
4.33	13	4.34	36		
4.25	17			4.26	35
3.90	16	3.90	57		
3.77	4	3.77	12		
3.57	35	3.576	31		
3.44	100	3.442	100		
3.34	75			3.343	100
3.32	31	3.317	67		
3.10	37	3.101	97		
2.83	16	2.834	53		
2.72	15	2.726	47		
2.48	5	2.481	14		
2.46	6	2.444	2	2.458	12
2.32	5	2.322	15		
2.28	3	2.281	7	2.282	12
2.21	8	2.209	27		
2.12	24	2.120	80		
2.10	25	2.104	76		
2.05	6	2.056	23		
1.98	4			1.980	6
1.93	3	1.930	7		
1.86	5	1.857	16		
1.81	13			1.817	17
1.79	5	1.787	3		
1.76	3	1.760	9		
1.67	9	1.673	14	1.672	7
1.63	1.8	1.636	8		
1.59	2	1.593	8		
1.54	7	1.534	18	1.541	15
1.53	4	1.536	11		
1.47	2	1.474	10		

Table 2. Trace elements concentration in barite veins

Elements (ppm)	Cr	Cu	Ni	Zn	Zr	Y	Pb	Sr	V	Nb	U*
Sample	20	8	4	11	u.d	2	14	49	134	3	u.d

u.d Under limit of detection
* Gamma-ray spectrometry

As previously mentioned, the barite veins are associated with El Haufhuf major fault and although various radiometric anomalies have been recorded in the altered sediments affected by this fault (Morsy, 1987 and El Agami et al, 2005), however, radioactivity is not associated with the studied barite mineralization. The lack of radioactive elements in the discovered barite mineralization is greatly advantageous in increasing its economic significance.

On the other hand, to define the mineral composition of the studied barite veins, the representative collected bulk composite sample was subjected to the XRD analysis. From the obtained results shown in Table 1, it was verified that the barite veins are only composed of barite and quartz.

In the meantime, to elucidate the purity of the studied mineralization a representative portion of the collected bulk composite sample was subjected to the XRF analysis to determine the presence of trace elements and their concentration (Table 2).

From the obtained data, it was revealed that the studied barite sample is almost pure where V and Sr assay 134 and 49 ppm respectively while the assay of Cr, Cu, Ni, Zn, Y, Pb and Nb ranges between only 2 and 20 ppm. In the meantime, Zr is under its limit of detection. In this regard, it is interesting to mention that a laboratory gamma-ray spectrometry has indicated that uranium is also under its limit of detection. These results indicate that except for Cr, the barite of Bahariya is almost not contaminated with harmful metallic elements; a matter which is greatly beneficial in reducing environmental hazards associated with the disposal of spent drilling mud.

LIBERATION INVESTIGATION

Wills (1979) noted that a correct degree of liberation is the key to the success in mineral processing, especially when the economic mineral is soft and the accompanied gangue mineral is hard. Although, some degree of separation is possible between locked particles by crushing , it should be evident that production of a reasonable degree of liberation is a pre-requisite to make a fair separation (Gaudin, 1980). As a mattar of fact, liberation is increased by comminution through two means; namely liberation by size reduction and liberation by detachment.

Due to the softness of barite and the the hardness of the accompanied gangue mineral (quartz), comminution must be carfully performed to avoid the possibility of overgrinding and excessive slime production. Accordingly, for the liberation investigation a controlled crushing was carried out on the representative bulk sample of the study barite vein in order to reduce the size of the head sample to pass 0.800 mm screen. The comminution process involved indeed a combination of jaw and roll mill crushers in a closed circuit. The crushed product was then deslimed using a desliming cone, dried and screened using a suitable set of screens; viz 0.800, 0.630, 0.400, 0.200, and 0.045 mm. The obtained size fractions were collected and a representative portion from each fraction was subjected to heavy liquid separation by bromoform. The obtained heavy and light fractions were then weighed and microscopically investigated under the binocular microscope to check mineral liberation. The microscopic examination for the various heavy fractions has actually indicated that barite represents almost exclusively the main constituent together with some scattered quartz crystals in some composite barite grains. The barite grains occur indeed as coarse massive crystals of vitreous luster and range in color from white to yellowish white. The crystals are transparent to translucent and are generally present in the form of angular to subangular shape. On the other hand, the heavy liquid separation of the bulk representative barite sample revealed that the average content of barite assays 56 % by weight of the original bulk rock sample and the rest is almost exclusively represented by quartz. It is quite clear that the weight percentages of the size fractions and their barite content increase with the decreasing of grain size (Fig. 3).

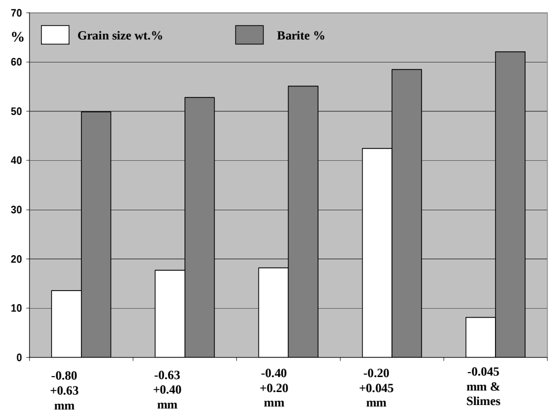

Fig. 3. Histogram show grain size distribution of the studied barite bulk sample and distribution of barite among various size fractions

Due to the variation in the friability between barite (a relatively soft mineral) and quartz, the degree of liberation of barite is relatively low in the two coarser size fractions i.e. -0.800+0.630 mm and -0.630 + 0.400mm; a matter which reflected in the presence of most barite grains as locked or composite crystals with quartz. However, microscopic investigation for the various size fractions indicated that both the degree of liberation and the percentage of barite increase with decreasing grain size.

Several liberated and composite barite crystals were hand picked and subjected to elemental analysis using the Environmental Scanning Electron Microscope (ESEM).

The SEM microphotograph (Fig. 4A) for a locked barite crystal (bright) together with quartz (dark) reflects the degree of liberation of barite in the coarser size. On the other hand, the back scattered images (Figs 4D and F) represent liberated barite and quartz

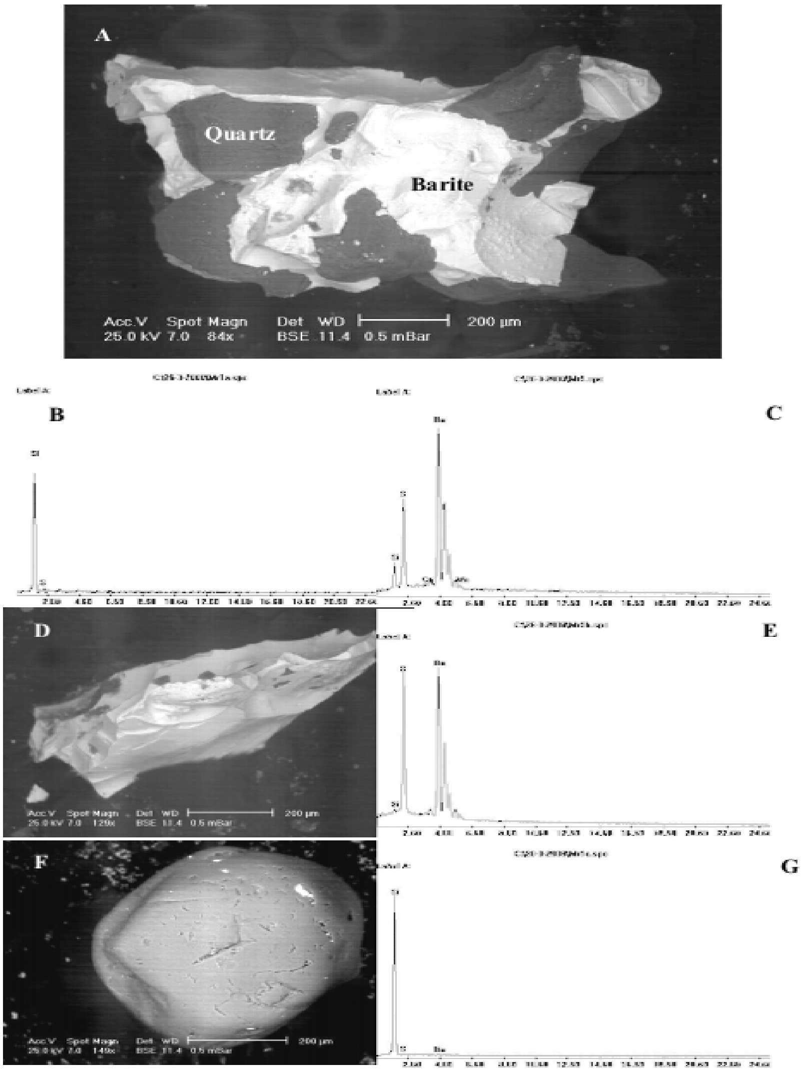

Fig. 4. A- backscattered image of composite grain consisting of barite (bright) and quartz (dark). B&C- chemical analyses spectra for barite and quartz respectively. D&E- BSE image for barite crystal and crossponding analyses. F&G- back scattered image of quartz grain and its chemical analyses.

crystals respectively. The corresponding EDAX analyses (Figs. 4 B, C, E and G) reflect the chemical composition of barite and quartz either in the locked or free grains. These analyses indicate that the major elements in barite are Ba (75.90%) and S (23.50%) together with a minor amount of silica.

Finally, it is interesting to mention that the quartz crystals were found to be present in two main habits in the studied barite samples. The first is represented by liberated rounded to subrounded crystals and have most probably attained their liberation by detachement rather than size reduction (Fig. 4F). The second habit is represented by angular to subangular crystals that are mainly present as locked crystals within barite (Fig.4A) and would thus attain their liberation by size reduction (Fig. 4D). The first type has been most probably brought to the already formed barite veins by mechanical weathering through wind and water currents. These rounded to subrounded quartz granules must have filled any cracks and fissures that have been formed after the formation of the barite veins. The second type is the silica that has been leached from the Tertiary basalt together with barium. The leaching fluids have subsequently filled the cracks and fissures to form the mineralization by rapid precipitation.

CONCLUSIONS

A high grade barite vein mineralization has been recorded for the first time in the ground surface of the El Bahariya Depression, Western Desert of Egypt. This mineralization is usually hosted in the sandstone beds of the lower Cretaceous Sabaya Formation and covers a great area south Gebel El Haufhuf. The barite veins occupy indeed the fractures that have been set up parallel to the main faults that are restricted in the Sabaya Formation. These fractures have actually been well developed along the fault zone trending E-W and NW-SE with more than 7m in length, a width ranging between 0.5 to 4m and a dipping angle attaining 50º towards NE direction.

A genetic model of the discovered barite mineralization has been proposed depending on barium leaching from the existing basaltic extrusion. On the other hand, it was mineralogically revealed that the discovered mineralization assays 56% by weight, associated with quartz as the sole gangue mineral. Liberation investigation indicated that a high liberation degree could be obtained in mesh size below 0.40 mm. Trace elements analyses has shown a very low assay where apart from V (134 ppm) and Sr (49 ppm), the other elements were found to range from only 2 to 20 ppm.

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Odnotowano występowanie mineralizacji barytowej na południe od Gebel El Haufhuf na powierzchni ziemi Obniżenia El Bahariya (Pustynia Zachodnia, Egipt). Żyły barytowe wiją się w różnych kierunkach i są związane z załamaniami i uskokami ograniczonymi do najstarszych skał piaskowcowych formacji Sabaya. Niektóre żyły mają 7m długości i od 0.5 do 4m szerokości. Żyły te zawierają do 65% wagowych barytu oraz kwarc. Omówiono mieneralizację i uwolnienie ziarn.

słowa kluczowe: mineralizacja barytowa, genetyka, uwolnienie, żyły barytowe