

Uranium Bearing Phosphorite, West Sibaiya, Egypt: Exploited Mines Characterization, and Potential of Surrounding Areas

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ABSTRACT

The study concerns petrographical, mineralogical, geochemical and radioactivity characterization of exploited phosphorite mines in West Sibaiya region, Nile Valley, Egypt to evaluate probable potentiality of the surrounding unexploited sites, there. Thirty phosphate and twelve shale samples are microscopically examined, X-rayed and chemically analyzed for major oxides and trace elements concentration as well as radiometrically measured and chemically analyzed for uranium. The interpretation of the obtained data reached to the following conclusive results:-

- 1-The west Sibaiya stratigraphic successions comprise the Qusseir Shale Member of the Nubia Formation unconformably overlain by the Duwi Formation consisting of lower, middle and upper phosphate members conformably followed upward by the Dakhla Formation.
- 2-The phosphate beds are composed of collophane ooids, peloids (55%) and, bioclasts of bone and teeth fragments. The phosphate beds consist of francolite and may be dahllite with minors of quartz, glauconite, chalcedony, strontianite and shell fragments embedded in amorphous silica, calcite, iron oxides and gypsum cement(in the lower phosphate member).
- 3- Geochemical vertical distribution recognized two groups of major oxides viz; P_2O_5 - CaO- MgO- F and SiO_2 - Al_2O_3 - Fe_2O_3 . The members of each show similar behavior.
- 4-The lower phosphorite member subjected to variable degree of phosphotization associated with dolomitization, silicification, and ferrugination enhanced by the recorded non-phosphatic constituents as well as oxidation to be yellow to brownish yellow in color and the lens-like undulated phosphate beds of the lower phosphorite member.
- 7- The average uranium content of the studied phosphorites (60 ppm) is to be leached from the manufactured phosphoric acid for producing safety fertilizers to avoid environmental pollution hazards.
- 8- Extensions of the undulated phosphorite beds in the surroundings lands of the exploited opencast mines in the region are probable to be recommended for detailed exploration and evaluation.

Key words: Uranium, phosphorite, exploited mines, characterization, Egypt.

Introduction

The phosphorite occurrences and deposits distributed in three east-west trending facies belts (Hermina, 1972); northern of no economic potential; central Nile Valley facies belt, the most economic occurrences, and southern Dakhla-Kharga belt. The phosphorites in Egypt are mined at three major regions on the Red Sea coastal zone (Safaga – Qusseir), on both banks of the Nile Valley, El Sibaiya east and west area, and Western Desert (Abu Tartur – Dakhla plateau). The phosphorite reserves in these localities are not clearly indicated. However, estimated geological reserves suggest about 70 million tons at Nile Valley (N.M.A Repost, 2010). During 2008 about 2 million tons of phosphorite ores were mined from the Sibaiya region (AFA Report, 2008); Morsery (1969); Philobos (1969); El-Kammar (1970); Attia *et al.* (1971) McClellan (1980), Germann *et al.* (1984), Baoumy *et al.* (2007). Zidan (2013) pointed out that collophane, bone and teeth fragments together with minor amounts of detrital quartz, carbonaceous and ferruginous material, pyrite, glauconite and

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shell fragments as the main constituents of the phosphorites at several localities along the Nile Valley.

Hassaan *et al.* (1992) recorded that Duwi Formation in Qusseir area at its type locality attains its maximum thickness (157.2 m). It chiefly comprises shale interbedded with sandstone facies at the base replaced at the top by carbonate facies. This phosphatic beds comprise sandy silicified phosphate, glauconite and sandy calcareous lithofacies. Its mineral constituents are quartz, anhydrite, apatite, calcite, dolomite, Mg calcite, chalcopryrite, monazite, aragonite, glauconite, hematite, siderite and kaolinite. The formation there, deposited in shallow, agitated abnormal saline, near shore to inner neritic, slightly reducing and alkaline, marine depositional environment and subjected to intense diagenetic processes namely, lithification, and phosphotization associated with dolomitization and ferrugination. In the respect, Hassaan *et al.* (2016) on studying the black shale belt including east and west Sibaiya district concluded deposition of the Duwi Formation shale interbedding the phosphate beds in oscillating marine shallow to inner neritic reducing environment supplied with muddy argillaceous sedimentation based on the recorded mud bands, goethite cubes pseudomorph after pyrite, organic matter (up to 22.33%), and total organic carbon (up to 2.15%).

The present study deals with geological, mineralogical and geochemical characterizations of the phosphorite bearing Upper Cretaceous Duwi Formation and its radioactivity in 4 old exploited mines namely from north to south; Mohamed Fouad, Najdi Abdel Fattah, Abdalla Abdel Jalil, Abdul Wahab Hsaballa, west Sibaiya area between Bisalyia Bahriya and Bisaliya Qebli, Nile Valley, Egypt. These mines are located between longitudes 32° 36' 58" and 32° 39' 08" E– and latitudes 25° 9' 50" and 25° 11' 15" N (Fig. 1).

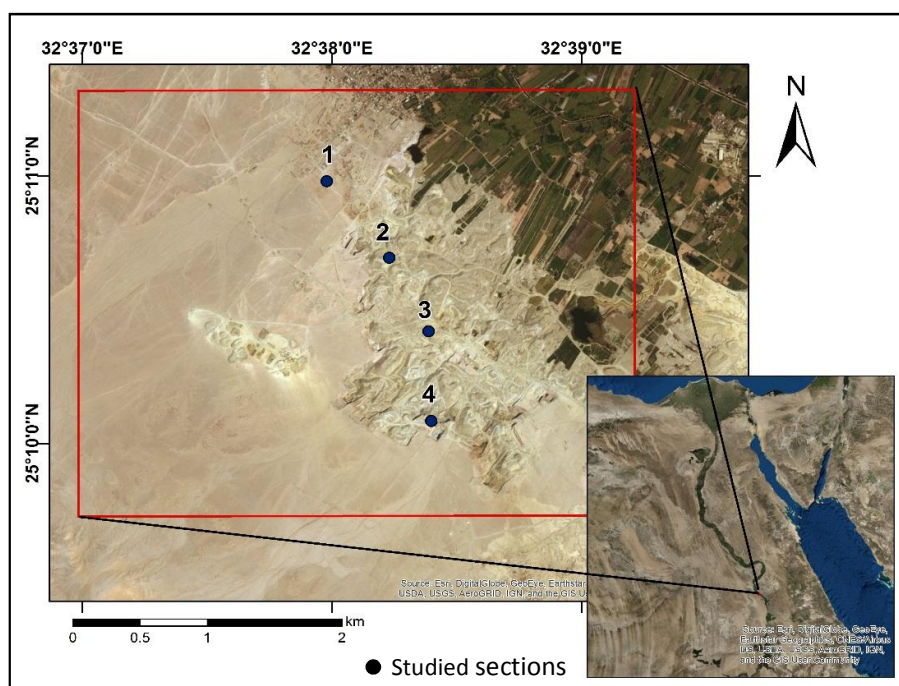


Fig. 1: Location of the studied area, west Sibaiya, Nile Valley.

2. Methods of Study

Four complete lithostratigraphic sections of the Duwi Formation cover all the studied area were subjected to field and sampling where 30 phosphate and 10 shale samples were collected. The sites of which are shown in the four figures of vertical distribution curves, chapter geochemical characterization.

Forty two thin sections were microscopically examined to identify the mineral constituents and textures. Besides, samples were X-rayed using PHILIPS PW 3710/31 diffractometer, scintillation counter; Cu-target tube and Ni filter at 40 kV and 30 mA.

The major oxides in the forty two samples were estimated using the conventional wet chemical

methods where SiO₂, TiO₂, Al₂O₃ and P₂O₅ contents were determined using the spectrophotometric method, Na₂O and K₂O contents were analyzed by the flame photometric method, Fe₂O₃, MgO and CaO by mean of EDTA volumetric method and loss on ignition, (L.O.I.) by heating at 1000°C after drying at 110°C. The content of the trace elements were determined using the XRF technique. The uranium and thorium concentrations were determined by multi-channel analyzer gamma ray spectrometer. The uranium content was chemically determined by LABOMED spectrophotometric coulometrically using Arenaso III method. All the analyses were carried out in the laboratories of the Egyptian Nuclear Materials Authority (NMA).

3. Lithostratigraphy

The Duwi Formation is phosphate bearing succession first described under the term Phosphate Formation by Youssef, (1949) in Gebel Duwi, west of Qusseir, Red Sea coast. Later Ghorab, (1956) described and named this unit as the Duwi Formation after its type section at Gebel Duwi along Red Sea Coast. Several stratigraphical studies were carried out on the Sibaiya area (e.g. Said, (1962), El Naggari (1966) and Issawi *et al.*, (1999) to classify the Upper Cretaceous-Lower Eocene succession in the Nile Valley region. They classified the sedimentary sequence in the study area into the following formations (from base to top):

Nubia Formation (Late Cretaceous): comprising mainly Taref Sandstone and Qusseir shale members.

Duwi Formation (Middle Campanian to Early Maastrichtian).

Dakhla Formation (Maastrichtian– Paleocene).

The Qusseir Shale Member is represented by variegated shale. The Duwi Formation is composed of oxidized, yellow to brownish yellow phosphorite, intercalated with thin black shale, dolomitic lenses and oyster limestone beds. This formation is conformably covered by the Dakhla Formation (Fig. 2 and 3a). It ranges in thickness from 19 to 22 meters and attains its maximum thickness in the studied area in the southern section (22 m). It is fossiliferous and includes some ammonites and other molluscan faunas in addition to some shark teeth. These fauna attributed the Duwi Formation to the Campanian (Nakkady, 1951; El-Naggari, 1966; Abd El-Razik, 1972 ;Kerdany and Cherif, 1990). The Campanian – Maastrichtian is considered the age of this formation by Youssef, (1957); Said, (1962); Hassanein *et al.*, (1993) and Issawi *et al.*, (1999) while Awad and Ghobrial, (1965); Akkad and Dardir, (1966); Hermina, (1967); Issawi *et al.*, (1978) of Lower Maastrichtian age. Ahmed *et al.*, (2013) studied the calcareous nano-fossils in both the Duwi Formation and the lower part of Dakhla Formation at Gebel Duwi section concluded that the Duwi Formation belongs to Upper Campanian age. The Duwi Formation in the studied area comprises three informal members; these are from base to top: lower, middle and upper members (Fig. 2 and 3b).

The lower member, the basal unit, is composed of yellowish brown phosphate beds at the exposed weathered surface, interbedded with thin blackish shale bands, lenses of dolomite, chert and oyster phosphatic limestone bed. The lower member is 2.6-3m thick with an average of 2.8m. The member attains a maximum thickness (3m) in the central part of the studied area (Fig. 2).

The middle member of the Duwi Formation is composed of grey to black, papery shale. The thickness of the middle member ranges from 17 to 20m thick with an average of 18.5m. The member attains its maximum thickness in the southern part of the study area.

The upper member is the uppermost unit of the Duwi Formation. It is composed of yellowish brown phosphate at the weathered exposed surface with dolomitic lenses and black shales. The upper member ranges in thickness from 15-30 cm. Its maximum thickness of 30cm is recorded in the northern part of the study area.

In the study area the Dakhla Formation conformably overlies the Duwi Formation and is composed of black fissile shale; intercalated with thin beds of silty clay, this Formation ranges in thickness from 1 to 4 meter with an average of 2m. The Dakhla Formation attains its maximum thickness in the studied area in the northern part (4m) relative to 2 m at the southern part.

4. Petrographic Features

Microscopically, the studied phosphate samples are composed of collophane grains, bone and teeth fragments, beside minor quantities of quartz, glauconite, and shell fragments embedded in silica, calcite, iron oxides and gypsum cement (Fig. 4a-f). Texturally, phosphorites have textures that resemble those in limestones viz; contain ooids, peloids, fossils (bioclasts), and clasts. These grains

are, of course, composed of apatite rather than calcite. Some phosphorites lack distinctive granular textures and are composed instead of fine, micrite-like, textureless collophane. No scheme for naming and classifying of phosphorites on the basis of texture appears to be in wide use at present time (Boggs 2009), because phosphorite texture is similar to limestone (e.g. peloidal, oolitic, fossiliferous). However some authors used modified limestone classifications to distinguish different kinds of phosphorites; Slansky (1986) classification based, to some extent, on that of Cook and Shergold (1986) classification, and Trappe (2001) adopted classification the modified by Dunham's (1962) carbonate classification.

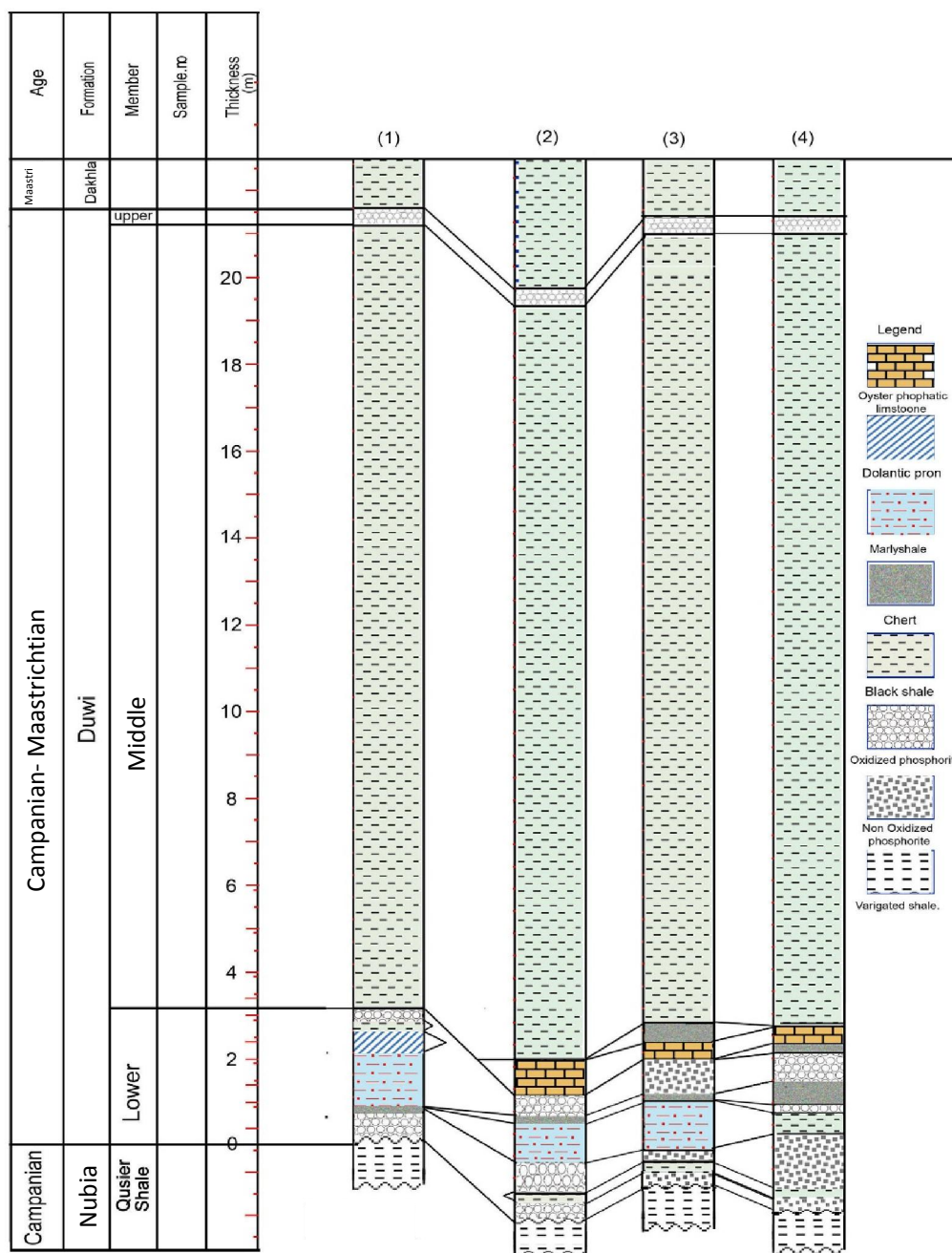


Fig. 2: Lithostratigraphic correlations of the studied mines, west Sibaiya area.

Texturally, the peloids possess different shapes and sizes. Peloids are essentially structure-less, apparently isotropic grains form about 55% of the phosphate grains in the studied phosphorite. Much of the phosphorite consists of pellets up to several millimeters in diameter are composed of collophane mineral. The color of the pellets varies from dark yellow to pale yellow, but occasionally exhibits a reddish-brown color due to ferruginous staining (Fig.4e).

The bioclastic grains are mainly medium, coarse to very coarse (up to 2mm), black, and brownish-yellow color. Teeth fragments with prismatic shape in a grey to black color are occasionally stained by red iron oxides (Fig. 4b). Bone fragments are present in different forms; generally made up of subangular to rounded elongated forms with grey to black color which sometimes transformed into brownish red as a result of iron oxide staining.

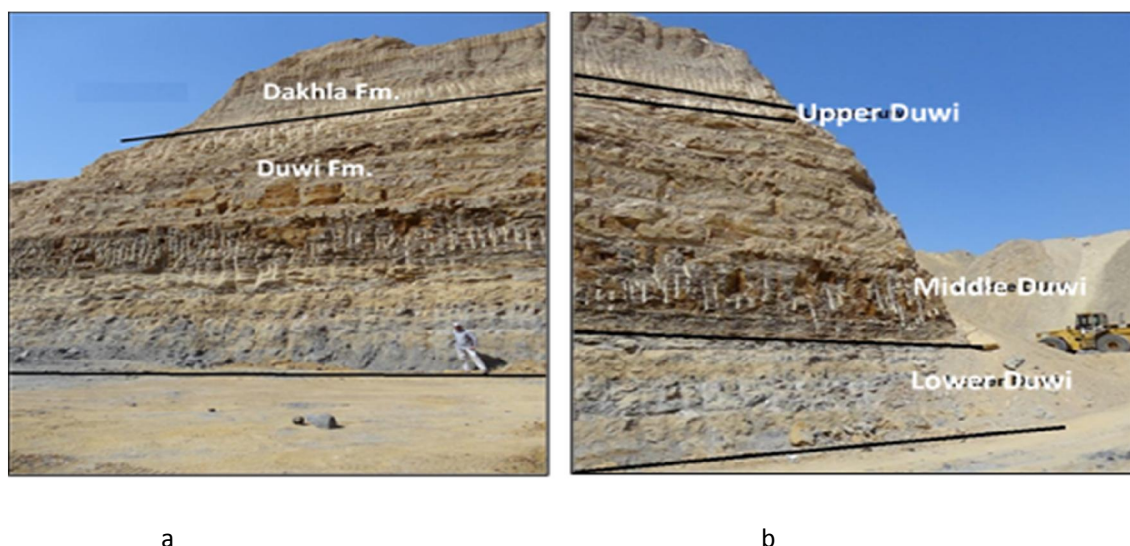


Fig. 3: Photographs showing: a) Duwi and Dakhla Formations; and b) Members of the Duwi Formation at west Sibaiya area.

The non-phosphate materials are detrital quartz and rarely authigenic glauconite. The detrital fine to very fine quartz grains are dispersed in some studied phosphate samples forming <5% of the rock. Cementing materials in the studied phosphorite are carbonates, iron oxides and amorphous silica in the form of chalcedony.

5. Mineral Constituents

The XRD data obtained for the studied phosphate samples recorded francolite as the major phosphate mineral constituent in the studied phosphate samples. However, dahllite also is may present as it is difficult to distinguish between the two minerals based on their diffraction lines. In this respect, X-ray diffraction patterns of francolite and dahllite (hydroxyapatite) are similar in their general appearance and intensity distribution (Bhatnagar, 1968).

The identified non-phosphate minerals in the studied phosphorites include: calcite, gypsum, quartz and dolomite (Figs. 5 and 6). Calcite is the major non-phosphate mineral constituent of the most studied phosphate samples. The petrographic study recorded calcite as cement but occasionally replaces the phosphate minerals in the bioclastic grains.

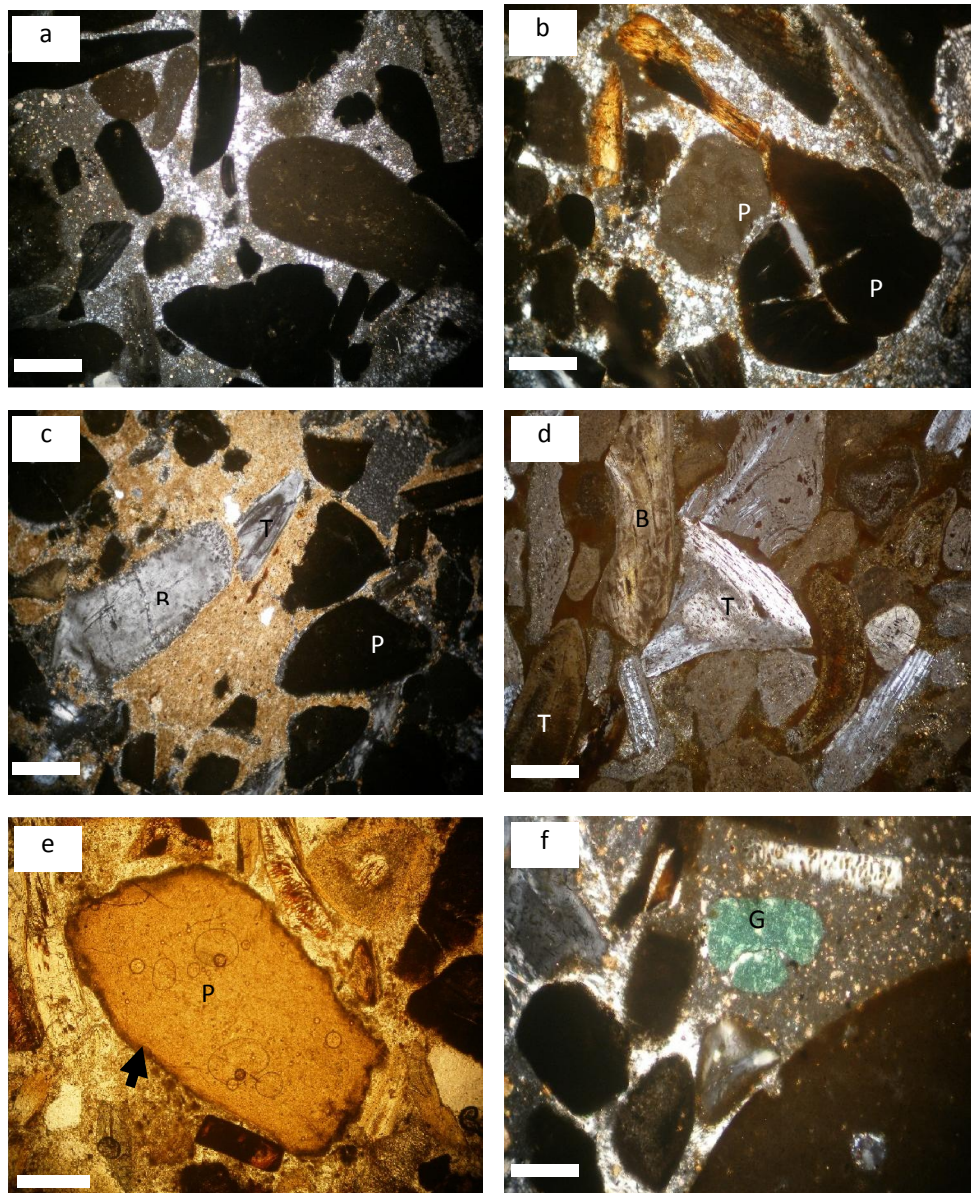


Fig. 4: Photographs showing different constitutes of the studied phosphorite: a) black and brown of colophane pellets (P) embedded in silica cement; b) colophane pellets (P) and ferruginated bone fragment; c) colophane pellets (P) with big teeth fragment (T) cemented by carbonates; d) teeth (T) and bone fragments (B) in close packing texture; e) large colophane pellets (P) coated by iron oxides (arrow) and; f) phosphatic grains, glauconite pellet (G) and matrix of fine quartz grains. Bare scale = 250 μ m.

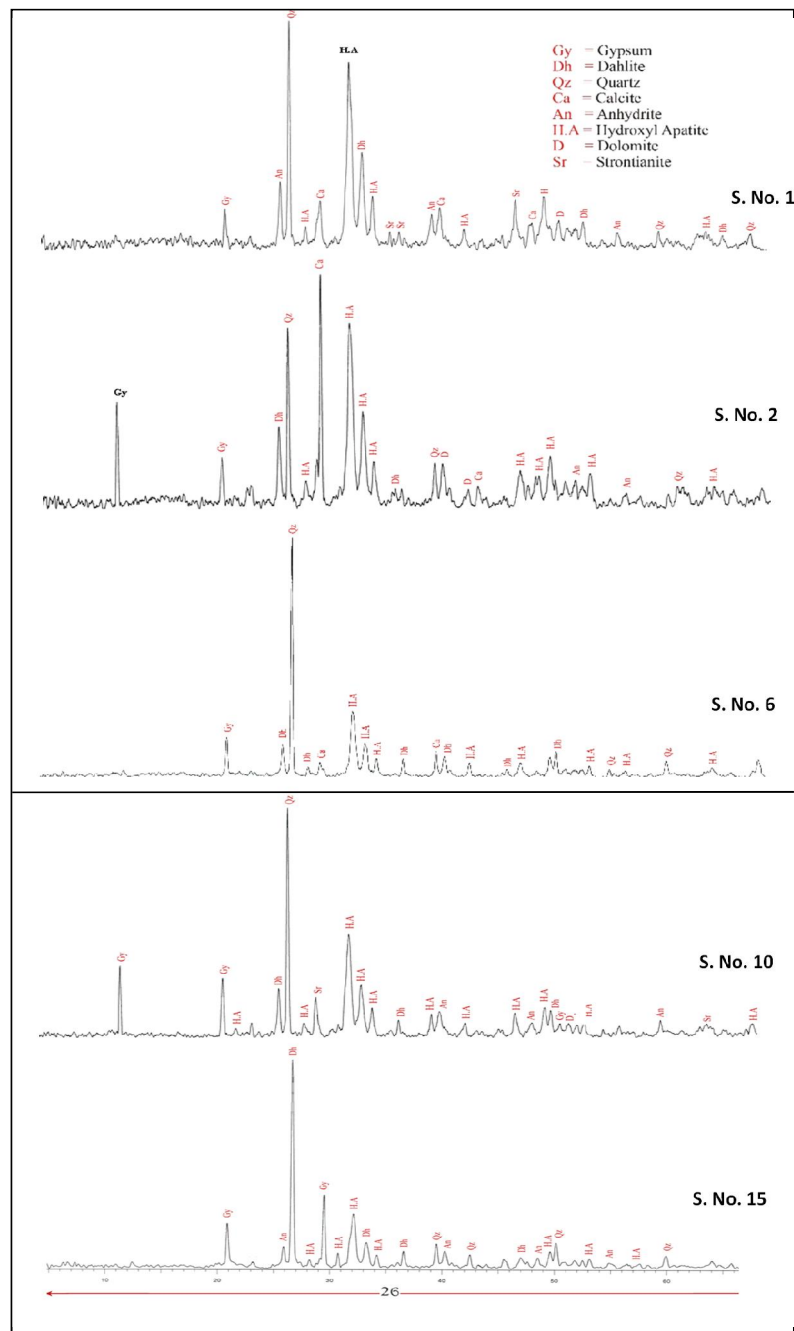


Fig. 5: X-ray diffraction pattern of phosphorite samples (sections 1 and 2) at west Sibaiya area.

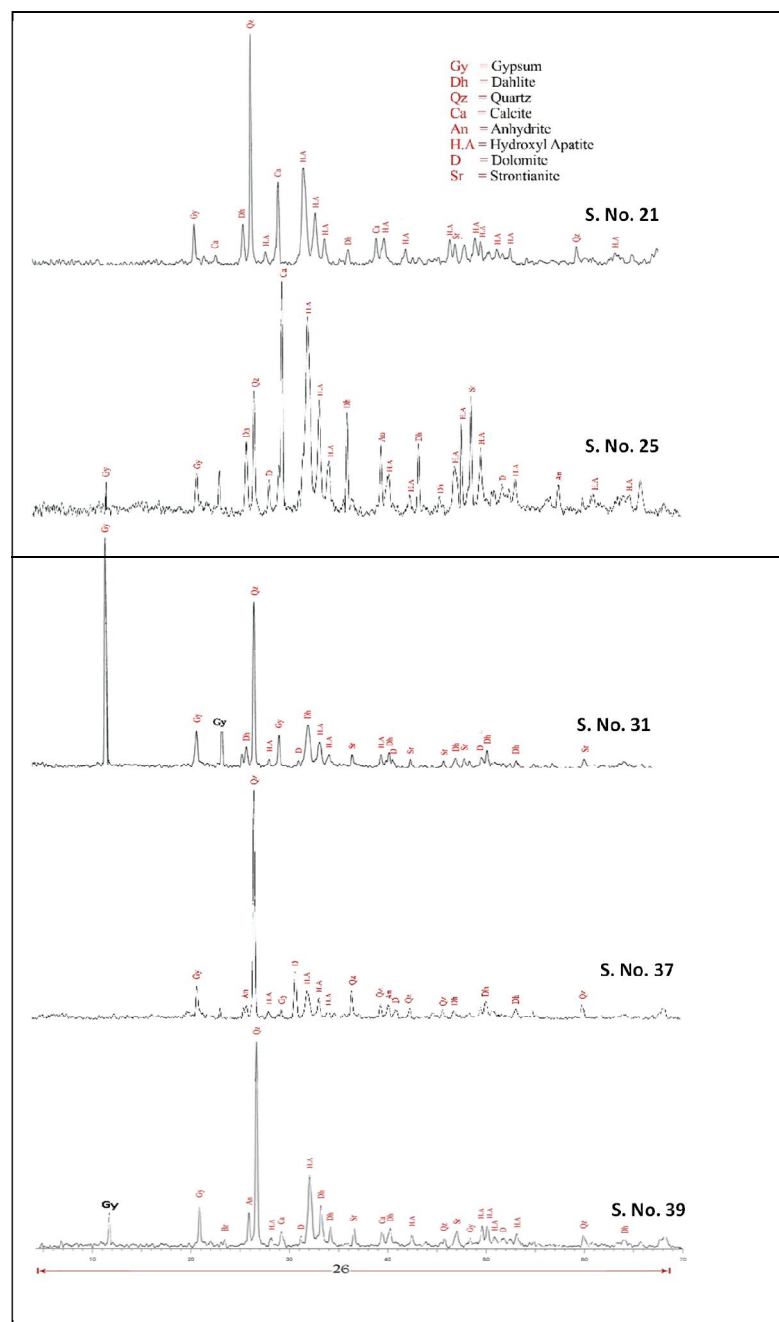


Fig. 6: X-ray diffraction pattern of phosphorite samples (sections 3 and 4) at west Sibaiya area.

Generally the quartz is much more abundant in Sibaiya phosphorite as detrital grains and crystalline silica (chalcedony). The microscopic examination recorded the enrichment of amorphous silica as cement as mentioned in the studied phosphorites.

Gypsum is common in weathered phosphate rocks and occurs as cementing material of flaky and fibrous crystals filling inter-granular pore spaces. Presence of gypsum in these samples is probably due to pyrite oxidation during the phosphatization diagenetic process and deposition or during the cementation processes. Such interpretation is supported by the recorded dolomite as minor constituent of most studied phosphate samples (Table 1) and ferrugination of phosphate grains. Moreover, strontianite (SrCO_3) is recorded in the oxidized lower phosphorite member.

Table 1: Distribution of phosphate and non-phosphate minerals in the studied phosphorite rocks.

Mineral S.No.	Hydroxyl- Apatite	Dahlite	Calcite	Dolomite	Quartz	Gypsum	Anhydrite	Strontianite
1	√	√	√	√	√	√	√	√
2	√	√	√	√	√	√	√	√
6	√	√	√	√	√	√	-	√
10	√	√	-	√	√	√	√	√
15	√	√	-	-	√	√	√	√
21	√	√	√	-	√	√	√	√
25	√	√	√	√	√	√	√	√
31	√	√	-	√	√	√	-	√
37	√	√	-	√	√	√	√	√
39	√	√	√	√	√	√	√	√

6. Geochemical Characterization

The obtained chemical analyses data of major oxides (%) of the studied phosphorite are given in table (2) exhibit several proper characterizations of each sample.

Table 2: Chemical analyses of major oxides (%) of west Sibaiya phosphorite.

Section No.	S.NO	P ₂ O ₅	CaO	MgO	SiO ₂	Fe ₂ O ₃	F	Al ₂ O ₃	Na ₂ O	K ₂ O	MnO	TiO ₂	L.O.I
1	1	27	39	4.6	10	4	2.1	1.6	1.3	0.2	0.01	0.02	11
	2	25	38.8	6.3	10.5	3.2	0.7	1.8	1.1	0.2	0.03	0.03	12.9
	3	25	37	4.5	10.8	5.1	1.5	1.8	1.1	0.2	0.04	0.02	11.2
	4	24.2	38.1	4.2	11	5	1.8	1.8	1.2	0.2	0.03	0.02	11
	6	25	37	4.9	10.9	4.1	2.3	1.9	1.1	0.3	0.02	0.01	10.7
	9	24.5	40	6.0	14.2	5.3	1.4	2.8	1.2	0.2	0.03	0.01	9
2	10	29	40	2.7	9	3	2.4	1.6	1.1	0.2	0.04	0.03	11
	11	28.2	41.3	2.7	9.7	3	3	1.6	1.2	0.2	0.05	0.02	8
	12	24.8	39	6.5	11.3	3	1	1.3	1.1	0.2	0.02	0.03	12
	13	28	41	4	10	4	1.5	1.2	1.2	0.2	0.03	0.02	10
	14	26.8	40	3.5	11	3.3	1.7	1.5	1.2	0.2	0.03	0.2	10.8
	15	26	39	5.3	9.2	4.8	1.9	2	1.1	0.2	0.03	0.03	9.7
	16	26.5	40.2	4.4	10.4	2.9	1.4	2.0	1.1	0.2	0.02	0.02	9.8
3	20	24.1	36.1	5.4	15	5	2.2	2.8	1.2	0.1	0.03	0.03	10
	21	27.0	41	4	10.9	3	1	1.3	1.2	0.2	0.03	0.03	11
	22	26	39	5	11.5	3.9	1.5	1.9	1.5	0.3	0.02	0.03	10.7
	23	26.4	39	3.8	10	3	0.9	1.4	1.2	0.2	0.02	0.02	11
	24	26	37.5	5.8	10.1	4	1.2	1.17	1.2	0.3	0.03	0.02	11
	25	26	39	6.2	10.1	4	1.3	1.7	1.1	0.2	0.02	0.15	12
	26	26	39	4.9	12	4	1.2	1.7	1.2	0.2	0.02	0.02	11
4	30	24	38.5	5.8	14	4.5	1.0	2.9	1.2	0.1	0.02	0.03	10
	31	27.5	40	2.8	9.2	3	2.5	1.6	1.2	0.2	0.08	0.02	11
	32	26	40	6	8	4	1.7	1.3	1	0.2	0.03	0.02	13
	33	27	39	3.3	11	5.1	1.3	1.4	1.0	0.2	0.01	0.02	9.0
	34	26.8	42.1	4	10	3	1	1.6	1.2	0.2	0.03	0.3	10
	35	25.5	38.3	5	10	4	0.7	1.3	1.1	0.2	0.03	0.03	14
	37	25.6	37.3	3.7	11.5	5.2	2.3	1.9	1.3	0.2	0.02	0.03	10
	38	25.1	40	4	10	5	2	1.8	1.3	0.2	0.02	0.04	11
Average	39	25	39	7	10.9	4.9	1.5	2.0	1.1	0.3	0.02	0.02	8.91
	42	24.5	39.5	4	14.4	3.7	1.8	2.4	1.3	0.2	0.02	0.02	11
Min.		24	35	2.7	8	2.9	0.7	1.2	1	0.1	0.01	0.01	8
Max.		29	42.1	6.5	15	5.3	2.5	2.9	1.3	0.3	0.08	0.3	14
Average		25.95	39.17	4.7	10.9	4	1.6	1.8	1.2	0.2	0.02	0.04	10.7

6.a-Major Oxides Distribution

1. The plotted distribution major oxides curves of the four successions recorded show similar behavior of two groups of chemical components SiO_2 , Al_2O_3 and Fe_2O_3 on the other hand P_2O_5 , CaO , MgO and F (Figs. 7-10). In this respect, three groups of major oxides that distinguish the phosphorites (Cook, 1972) are CaO , P_2O_5 , F , CO_2 , Na_2O within the apatite lattice, SiO_2 , Al_2O_3 , K_2O , TiO_2 of the detrital origin and the Fe_2O_3 , MgO , MnO of chemical weathering. The major element chemistry of unaltered francolite is mainly determined by the principal substitutions and displays only little variation of the composition of 32% P_2O_5 , 52% CaO , and 4% F (McArthur, 1978 & 1985; Jarvis *et al.* 1994).

2. The chemical composition of these phosphorite beds match with the averages of the published data of other localities of the world given by McArthur (1978, 1985), Jarvis *et al.* (1994) for example. The $\text{CaO}/\text{P}_2\text{O}_5$ ratio in the studied phosphorite (≈ 1.5) is match well with that given in these published works (≈ 1.6).

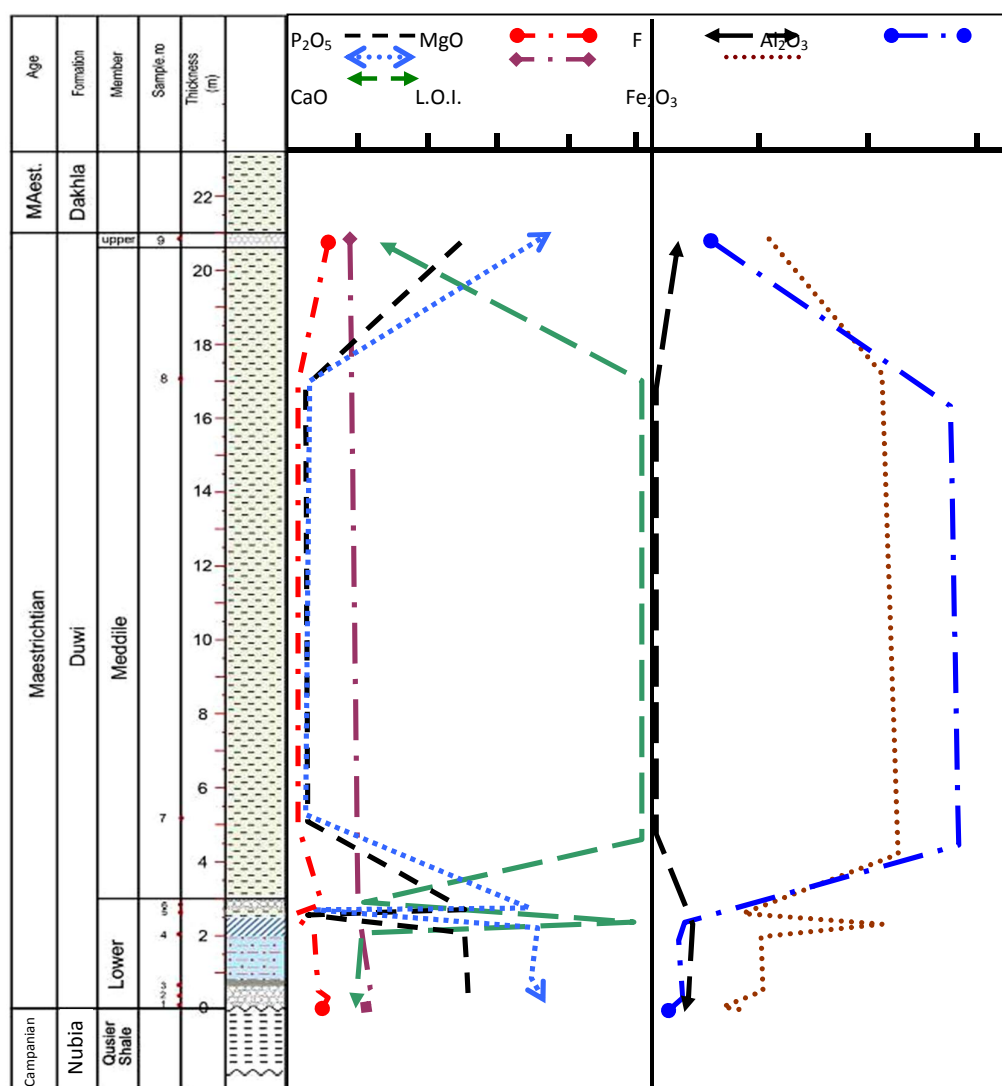


Fig.7: Vertical distribution of major oxides of the studied section No.1.

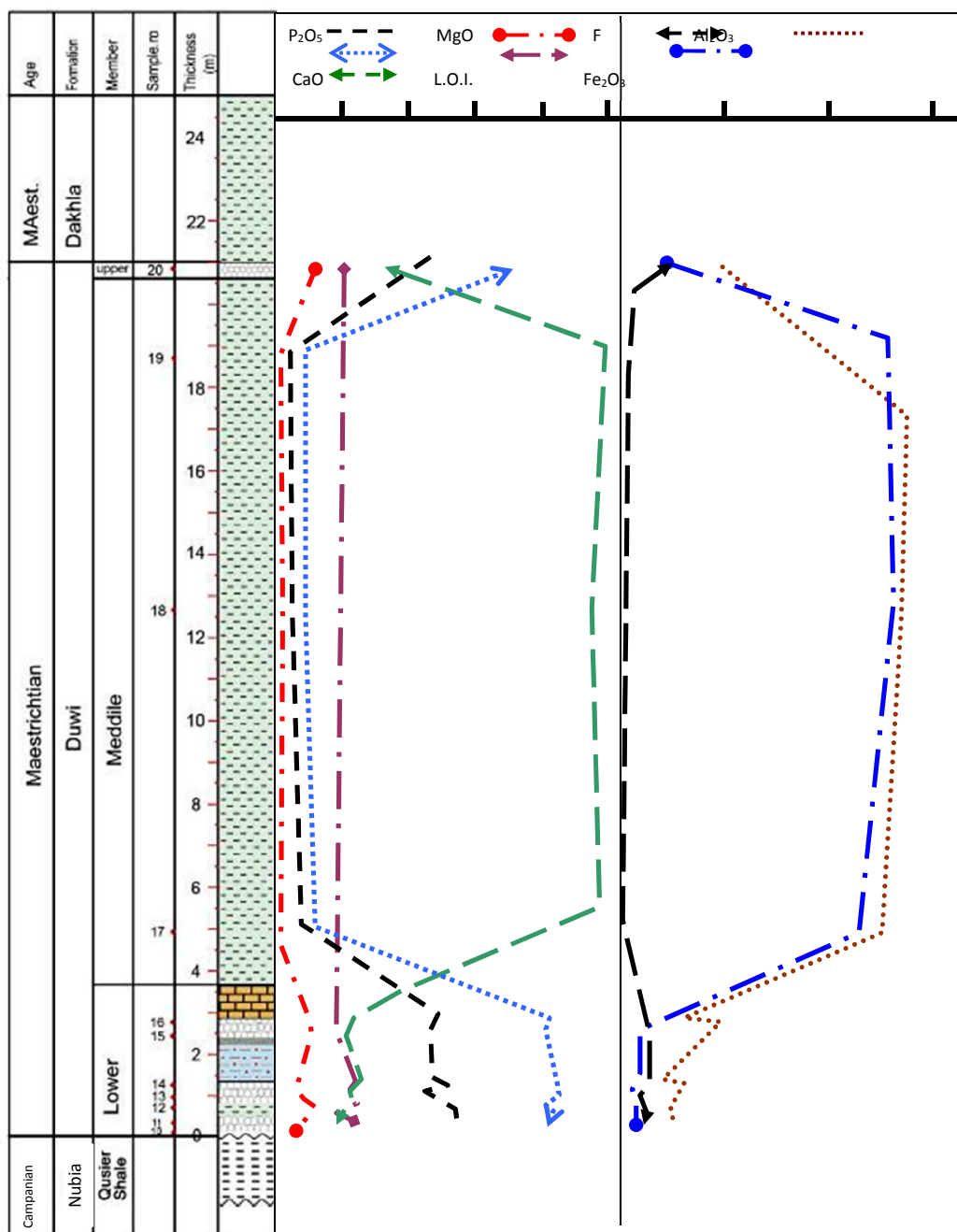


Fig. 8: Vertical distribution of major oxides of the studied section No.2.

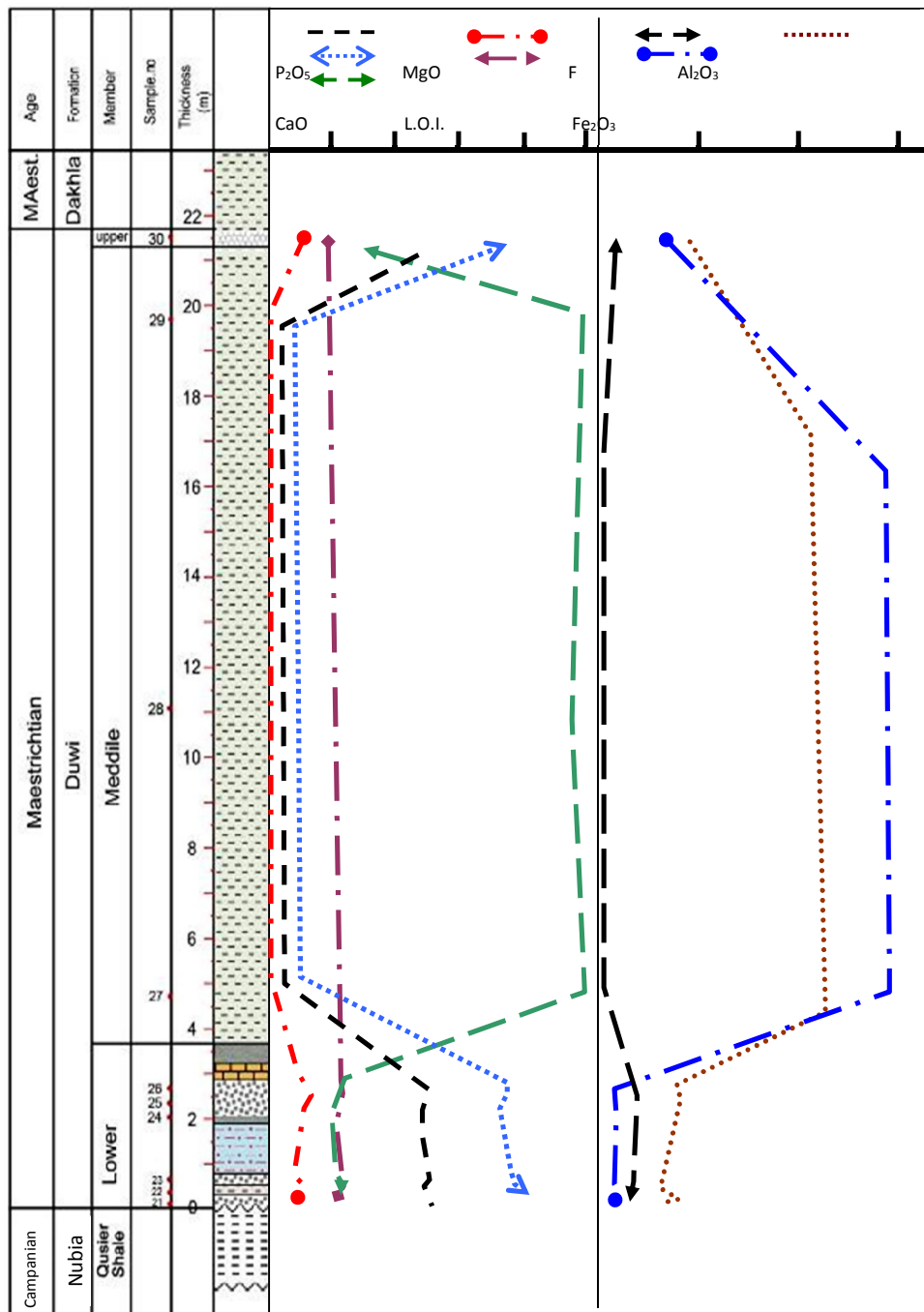


Fig. 9: Vertical distribution of major oxides of the studied section No.3.

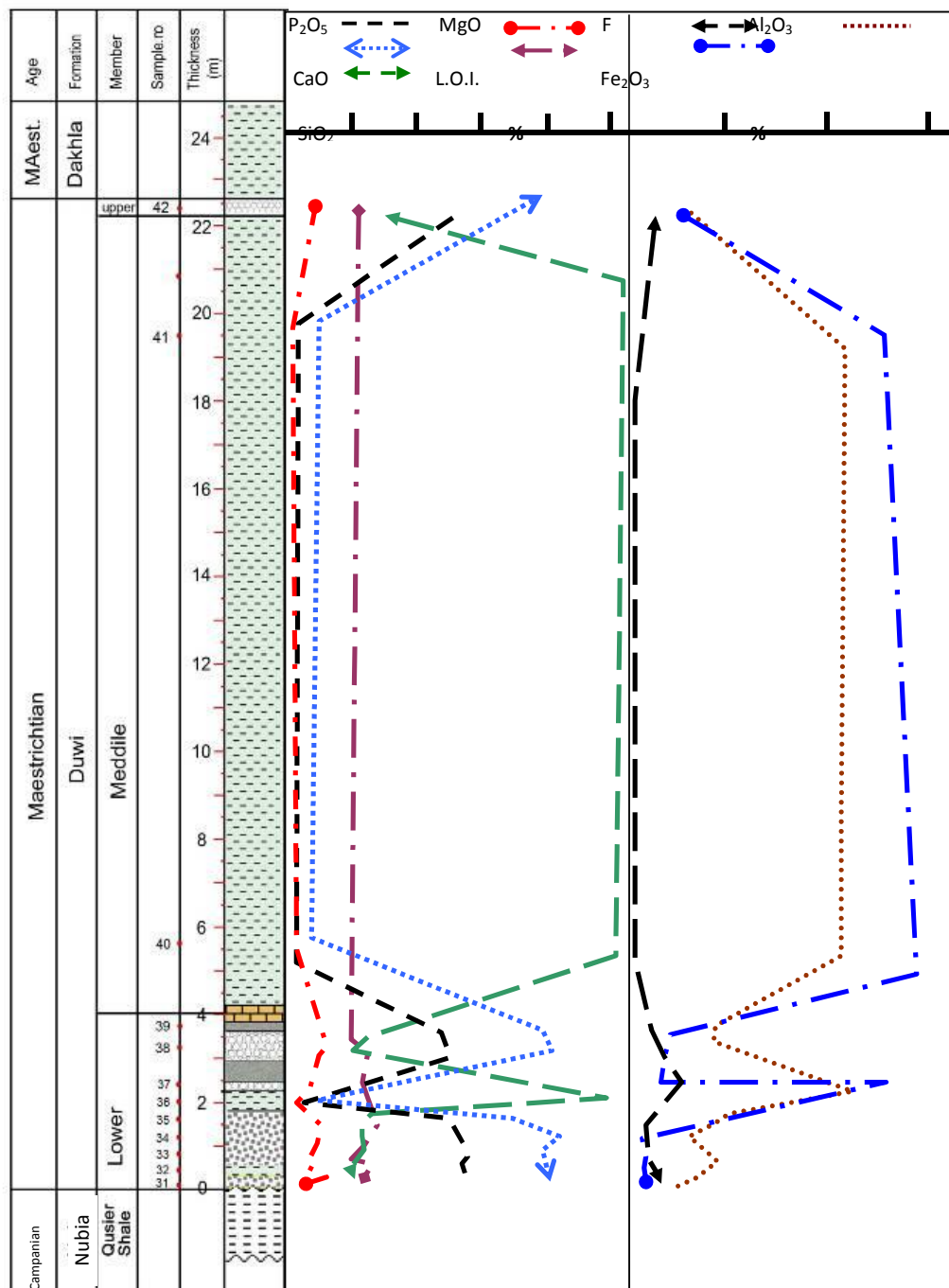


Fig.10: Vertical distribution of major oxides and F of the studied section No.4.

3. Calcium oxide, the chief chemical component forming with P_2O_5 apatite, recorded slight decrease (39.17%) compared to that of P_2O_5 (25.95%). This may be due to the substitution of Ca^{+2} by the recorded F (2.5 - 0.7%), MgO (6.5 - 2.7%). Many substitutions of F in the fluorapatite structure are possible (Boggs, 2009). The decrease in CaO content is associated with increase of MgO (4.9 - 7%) as appear in figures (7 - 10) that may be attributed to the diagenetic dolomitization process as approved by the recorded thin dolomitic lenses at several levels of the studied Duwi Formation (Fig. 2).

The fluorine content increases through diagenetic processes by both the microbial action on phosphatic grains (Boggs Op. Cit) and/or consolidation of phosphatic sediments (Baturin 1982). Fluorine accumulates in biogenic phosphatic material subjected to diagenetic phosphatization, where the content increases from (0.7 - 3.4%) in the scales to bones and from (1.50 - 5.48%) in phosphatized coprolites. In the course of phosphorite formation the fluorine content somewhat rises up during lithification of phosphorite sediments. Also F/P₂O₅ ratio increases in the order of phosphatized sediments. Unconsolidated phosphate concretions - lithified phosphorite concretions shows that accumulation of fluorine in the concretions takes place somewhat in advance of phosphorus (Op. Cit).

4. The chemical concentrations of SiO₂ (up to 15%) and Al₂O₃ (up to 2.9 %) in the studied phosphorite samples reflect the recorded detrital quartz grains and/or amorphous silica in the form of chalcedony as cementing material, rather than to clay minerals (Fig. 4). The replacement of phosphate minerals by silica has been reported in Sibaiya phosphatic rocks by (Abd El-Moghny, 2011).

5. The studied phosphorite contains slight higher Fe₂O₃ content due to the recorded hematite as staining of the phosphatic pellets. The hematite is mainly formed during diagenetic processes may be due to oxidation of pyrite and/or glauconite which always associate the phosphatic rocks to release Fe, S and forming hematite, gypsum and MgO forming dolomite respectively. Gypsum and hematite are recorded in the XRD charts (Figs. 5 and 6).

6.b- Trace Elements Distribution

The analyses of trace elements in the studied phosphorite of the Duwi Formation (Table 3) show nearly similar average contents of Sr (757ppm), and Cr (116ppm) and poor Cu (24ppm), Ni (36ppm), Pb (5ppm) and Zn (122ppm) compared to marine phosphorite forgiven by (Altschuler, 1980). These elements are related to both replacement of the apatite lattice structure (e.g. Sr) and adsorption onto organic matter (e.g. Pb, Ni).

The XRD data recorded presence of strontianite as accessory mineral in some samples of lower phosphorite member (Figs. 5 - 6). Strontium, Ba, and Zn exhibit a marked affinity towards fixation in the apatite crystal lattice (Altschuler, 1980). Moreover, Sr can be concentrated in tests and shells up to 10% (Kulp *et al.*, 1952). In this respect, Sr releases quickly from apatite crystal lattice (Lucas *et al.*, 1980) to combine with the liberated CO₃²⁻ forming strontianite beside formation of dolomite during the phosphatization diagenetic process. All marine carbonate fluorapatites when formed have the same Sr content (0.24%), the recorded variations are due to later action (McCarthy, 1978).

Chromium, Ni, V and Pb contents are most probably adsorbed onto organic matter (El-Kammar 1974). Prevot and Lucas (1980) mentioned that Cr is primarily carried by apatite and is further fixed in clays. The elements Cu, Cr, Ni, Pb, and V show a strong affiliation to the phosphate fraction in sediments (Jarvis, 1992).

The elements which are not preferentially substituted such as Sr in the apatite lattice are commonly depleted in the phosphate fabrics. Piper and Medrano (1995) demonstrated that the complexity of the source and location of trace elements in phosphorite rocks. Many trace elements, such as Ag, Cd, Mo, Sr, U, Zn, and REEs may also be present in the phosphorite in amounts commonly exceeding their average concentrations in seawater, the crust, and the average shale (Nathan, 1984).

The binary relationships shown in diagrams (Fig. 11) confirm such relations. The calculated correlation coefficient (r) values of trace elements show significant confident positive correlations of CaO, Sr and U with P₂O₅ and negative correlation with MgO, SiO₂, Fe₂O₃ and Al₂O₃.

6.c- Distribution of Radioactive Elements

-U content

The radiometric U content in the studied phosphorite ranges from 40 to 75ppm with an average value of 54ppm, while chemical uranium ranges from 43 to 80ppm with an average value of 60ppm (Table 3). On other hand, the average uranium content in the studied west Sibaiya phosphorite (60 ppm) is low compared to those of east Sibaiya (76 ppm, Negm, 2014) and Red Sea (68 ppm) (Zidan, 2012) and is high compared to Abu Tartur phosphorite (23 ppm) (Zidan, Op. Cit). Presence of U in

Sibaiya phosphorite incorporated in the apatite lattice while the other trace elements adsorbed on clay cement as mentioned by (Zidan, 2013).

-Th content

The Th content in the studied phosphorite ranges from 1 to 6ppm with an average value of 3ppm. Generally, this average content of Th (3 ppm) compared to that in the east Sibaiya phosphorite (3 ppm) by Negm (2014) is similar low in Red Sea and Abu Tartur phosphorites (4 and 5ppm) by Zidan (2012).

- Ra content

The average Ra content in the studied phosphorite of west Sibaiya area (65 ppm) is low compared to east Sibaiya phosphorite (Negm, 2014) and high the Red sea and Abu Tartur phosphorites (Zidan 2012).

Table 3: Chemical analyses of trace elements (ppm) of west Sibaiya phosphorite.

Secti on No.	S.N o.	Cd	Cr	Cu	Ni	Zn	Pb	Sr	cU	eU	Th	Ra	cU/T h	eU/ Ra	cU/e U
1	1	3	115	11	30	123	2	712	77	70	4	73	19.2	0.95	1.1
	2	11	109	28	48	150	4	619	43	41	3	52	14.3	0.78	1.04
	3	9	30	27	44	165	1	562	52	44	1	57	52	0.77	1.18
	4	11	111	32	40	72	2	544	49	47	3	54	16.3	0.87	1.04
	6	6	76	29	38	95	12	639	50	51	2	50	25	1.02	0.98
	9	11	147	28	45	153	7	571	56	41	1	45	56	0.91	1.36
2	10	21	85	26	29	176	8	1566	68	61	3	67	22.6	0.91	1.11
	11	17	116	25	41	183	11	1561	50	42	1	55	50	0.76	1.19
	12	6	129	23	27	81	2	583	58	50	6	63	9.6	0.79	1.16
	13	17	125	11	12	130	11	1432	79	72	5	74	15.8	0.97	1.09
	14	13	158	19	44	181	8	791	74	67	2	78	37	0.85	1.1
	15	10	160	31	46	144	5	680	62	51	3	65	20.6	0.78	1.21
	16	9	102	29	42	191	7	714	68	65	2	78	34	0.83	1.04
3	20	8	155	26	42	158	4	526	48	40	4	53	12	0.75	1.2
	21	9	131	10	20	140	3	913	62	56	2	68	31	0.82	1.1
	22	9	71	31	39	157	9	640	61	56	2	70	30	0.8	1.08
	23	17	114	24	35	69	4	733	74	68	2	78	37	0.87	1.08
	24	4	151	26	43	127	6	711	55	58	4	65	13.7	0.89	0.94
	25	10	89	29	41	157	9	671	61	44	3	46	20.3	0.95	1.38
	26	18	143	27	35	19	11	654	60	52	2	70	30	0.74	1.15
4	30	10	113	33	41	72	3	533	51	46	4	59	12.7	0.77	1.1
	31	7	96	27	43	154	3	782	80	75	2	76	40	0.98	1.06
	32	20	113	30	39	24	9	721	58	51	6	63	9.6	0.8	1.13
	33	4	135	11	12	168	2	861	72	68	5	73	14.4	0.9	1.05
	34	6	97	26	43	155	1	842	44	40	5	56	8.8	0.71	1.1
	35	14	132	21	31	14	5	661	53	49	1	66	53	0.74	1.08
	37	9	122	11	18	143	3	1632	60	54	3	69	20	0.78	1.11
	38	13	135	19	33	13	6	694	50	45	3	65	16.6	0.69	1.11
Average	39	11	115	28	45	205	4	617	50	43	6	63	8.3	0.6	1.16
	42	14	117	18	37	36	1	544	79	72	5	85	15.8	0.8	1.09
Min.		3	30	10	12	13	1	526	43	40	1	45	8.8	0.6	1.04
Max.		18	160	33	46	205	12	1566	80	75	6	85	56	1.02	1.38
Average		10.9	116.4	23.8	36.1	121.83	5.43	790.3	60.13	53.96	3.16	64.53	24.85	0.826	1.11

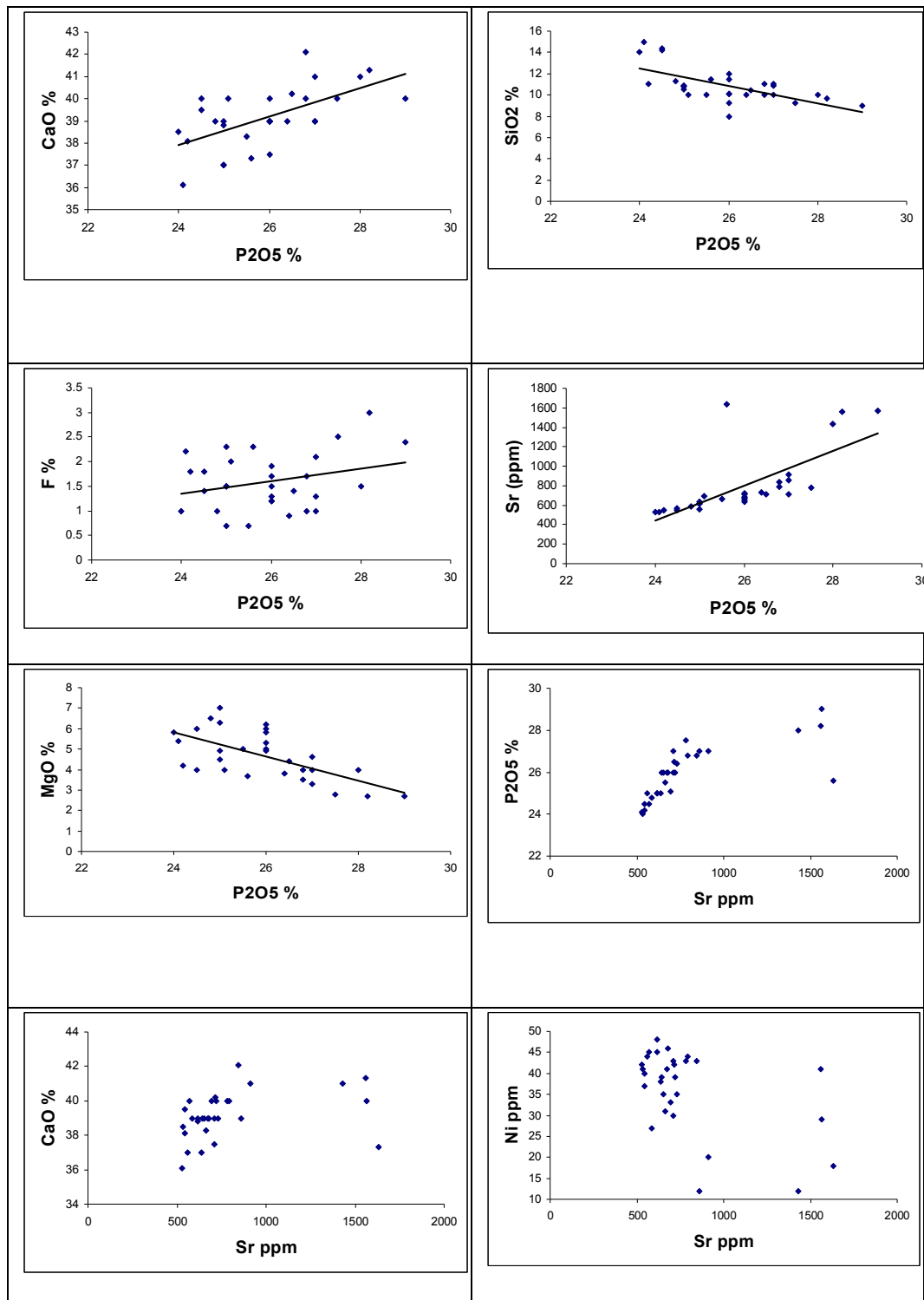


Fig.11: Correlation between major oxides (%) and trace elements (ppm) in West Sibaiya phosphorite.

- U/Th Ratio

The average (cU / Th) ratio of west Sibaiya phosphorite, (Table 3) indicates high degree of uranium mobilization and enrichment. The equilibrium factor P-factor (eU/Ra) is less than the unity,

indicating disequilibrium state due to a removal of the uranium than radium (Naumov, 1959). Also, these results are confirmed by the calculated D-factor (cU/eU) which is mainly more than the unity reflecting slightly disequilibrium state with addition of uranium (Adams and Weaver, 1958).

In consequence, west Sibaiya phosphorites due to the relative enriched uranium can be recommended only after leaching uranium to the permissible level for manufacturing phosphoric acid and the phosphate fertilizers to avoid environmental hazards. Zidan, (2012) reported, that the highest concentrations of U and Ra in the Egyptian phosphatic fertilizers about average 74 and 85 ppm respectively. The sources of the manufactured of fertilizers were from Sibaiya and Red Sea phosphorites.

In this respect, removal of U from manufactured phosphoric acid from west Sibaiya phosphorite is recommended and in particular to produce safety phosphate fertilizer.

7. Conclusions

- 1-The West Sibaiya stratigraphic successions comprise the Qussier Shale Member of the Nubia Formation unconformably overlain by the Duwi Formation consisting of lower, middle and upper phosphorite members conformably followed upward by the Dakhla Formation.
- 2-The studied phosphates are composed of collophane, ooids, peloids (55%), and bioclasts of bone and teeth fragments. Besides, minors of quartz, glauconite, chalcedony, strontianite and shell fragments are embedded in amorphous silica, calcite, iron oxides and gypsum cement (in the lower phosphate member). The XRD showing francolite and may be dahllite (hydroxyl-apatite) as phosphatic minerals due to diffraction lines interference.
- 3- Geochemical vertical distribution recognized two groups, the major oxides of each exhibit similar behavior. These are P_2O_5 - CaO- MgO - F and SiO_2 - Al_2O_3 - Fe_2O_3 reflecting diagenetic phosphotization effect. The low CaO content compared to that of P_2O_5 is due to F substitution for Ca forming francolite (fluor-carbonate apatite) representing such effect.
- 4-The three phosphorite members subjected to variable degree of phosphotization associated with dolomitization, silicification, and ferrugination evidenced by the recorded calcite, dolomite, chalcedony (amorphous silica), hematite, iron staining and strontianite.
- 5-The intense phosphotization effect on the lower phosphorite member is supported by its intense oxidation to be yellow to brownish in color compared to the middle member.
- 6- The phosphotization diagenetic process caused the lens-like undulatory format of the phosphate beds of the lower phosphorite member.
- 7- The average uranium content of the studied phosphorites (60 ppm) is low compared to those of East Sibaiya (76 ppm) and Red Sea (68ppm) and is high compared to Abu Tartur phosphorite (23 ppm). However, uranium is to be leached from the manufactured phosphoric acid for producing safety fertilizers to avoid environmental pollution hazards.
- 8- With regard to the undulated phosphorite beds, the surroundings of the exploited opencast mines in West Sibaiya region probably potentially bearing extensions of phosphorite are recommended based on effect of phosphotization for detailed exploration and evaluation.

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