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PETROGENESIS OF SELECTED PEGMATITIC BODIES FROM EASTERN DESERT AND SINAI MASSIF, EGYPT

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ABSTRACT

Selected pegmatitic bodies of simple and complex types (unzoned and zoned) located in the Eastern Desert (ED) and Sinai Massif (SM) have been carefully studied. The simple pegmatites under consideration occur at Wadi Hawashia (northern ED), Gabal El Hudi area (southern ED) and Wadi Dahab (SM) forming irregular lenses and pods. Alkali feldspar, quartz and muscovite pockets represent the essential mineral constituents. On the other hand, the complex types of zoned nature occur at Gabal Abu Dob (central ED) and Wadi Um Shoki (SM) forming sheets and dyke-like appearance. They constitute a sequence of mineral assemblage from the contacts inward as follows: alkali feldspar ± mica pockets followed by graphic quartz and quartz megacrysts at the core. Almost all pegmatitic bodies invade granitoids with a mild contact effect (if present).

Petrographically, the pegmatites are granitic (comprise alkali feldspar granite constituents as perthite, microcline perthite, quartz ± mica) and perthitic (string, patch and net types of perthite are the main mineral constituents). Allanite, zircon, apatite, cassiterite and uranophane are mostly accessories.

Geochemically, almost all pegmatites have metaluminous to peraluminous nature and are characterized by their high alkali contents (up to 12 wt%) as well as low CaO contents (< 1.0 wt%). Regarding to mineral chemistry, the perthite analyzed lies in the field of alkali-feldspar-rich rocks. Composition of Mg-mica (manganophyllite) is distinguished by elevated abundances of alumina, magnesia and manganese contents.

Textural and mineralogical features of manganophyllite suggest late-crystallized phase with variable degrees of metasomatism of an initial source rock. It is quite clear from the field, petrographic and geochemical studies of the present pegmatites that these rocks seem to be strictly of magmatic nature in one hand and in combination with metasomatism associated with volatile input in another hand.

INTRODUCTION

The present work deals with some important pegmatitic occurrences in Egypt that were previously studied by many authors. A suite of five occurrences of pegmatites have been carefully studied; W. Hawashia, G. Abu Dob and W. El Hudi in the Eastern Desert and W. Um Shoki and W. Dahab in Southern Sinai. Their locations are listed in table 1 and mapped in fig.1.

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Table (1): The studied pegmatites and their location coordinate.

Pegmatitic body	Longitude	Latitude
W. Hawashia	32° 29'E	28° 15' N
G. Abu Dob	34° 25'E	25° 25'N
W. El Hudi	33° 10'E	24° 4' N
W. Um Shoki	34° 21'E	28° 32'N
W. Dahab	34°23'E	28° 32'30''N

GEOLOGY

Eastern Desert Pegmatites

In Wadi Hawashia, the pegmatitic pods are concentrated in the alkali-feldspar granites taking different forms (Fig. 2A) (circular to elongated) and variable dimensions (unmappable bodies to immense bodies quarried for quartz and feldspars). They are of unzoned type occurring as simple pegmatites including quartz, alkali feldspar or quartz and alkali feldspar together (Fig. 3A). On the other hand pegmatitic mica occurs as pockets associating the quartz and feldspar. It is characterized by brown colour due to the high content of iron oxides (Fig. 3B).

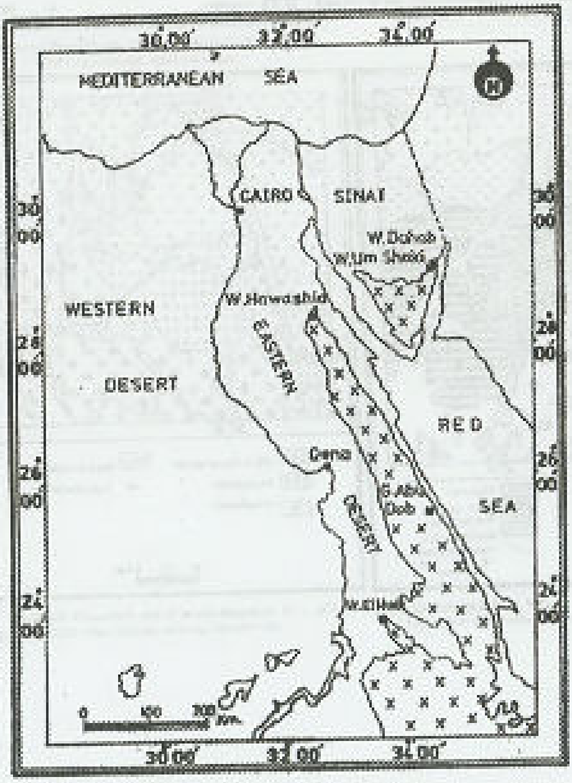
Gabal Abu Dob represents the eastern flank of Kadabora boss and it is composed mainly of younger granite (Fig. 2B). Pegmatites occur as irregular bodies or lenticular bodies cutting the younger granite with sharp contacts (Fig. 3C). The irregular bodies are characterized by sub-parallel and radial fabrics which grew in open spaces forming columnar, prismatic or leaf-like forms. They are characterized by obvious zonation starting with alkali feldspar at the intermediate zone followed by quartz at the core. Quartz occurs as very coarse crystals of different colours; rose, milky white or white dissected by numerous fractures filled by dusty black materials. Alkali feldspar also occurs as giant crystals varying in colour from pale buff to pink. Most of the lenticular bodies are completely composed of mica of flaky appearance. They occur as giant crystals varying in color from deep red to black (Fig. 3D).

The pegmatites of Wadi El Hudi occur as sheets or lenses that reach about 20m in thick occurring parallel to the foliation of the surrounding migmatites (Fig. 2C). They occur as widespread bodies of potash feldspar and quartz characterized by cubic forms due to the effect of fractures and joints (Fig. 3E). The pegmatitic quartz also occurs in radiated forms controlled by prevailing structure (Fig. 3F).

Sinai Pegmatites

Wadi Um Shoki pegmatites occur as unmappable body of complex pegmatite hosted by monzogranite (Fig. 2D). They occur as small plateau taking the form of extended cone with its apex pointing northeast (Fig. 4C). The body displays several zonal colours starting by the pink colour of the younger granite in the foothills followed by the buff color of feldspars and the milky colour of quartz (Fig. 4B). Pegmatitic rocks also occur as fracture filling in the granite.

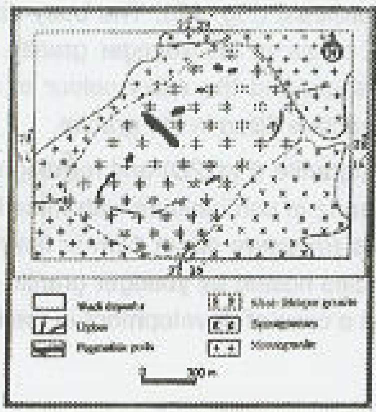
Dahab pegmatites are hosted by monzogranite (Fig. 2D) and forming simple type of alkali feldspar (Fig. 4C) and/or quartz in combination with mica flakes. They occur as small and elongated bodies (measure about 12m in length and 1.5m in width) and as equidimensional bodies hosted by younger granite rocks. Their sizes, shapes and frequency suggest a case of development in the hosing granites.



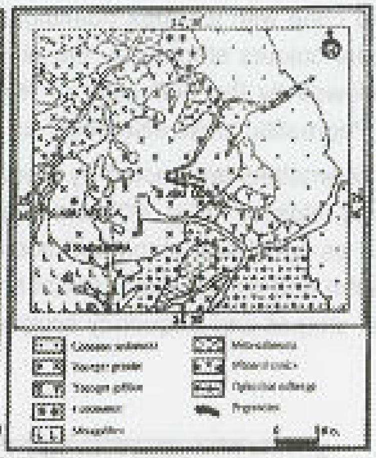
(Fig.1.): Location map showing the studied pegmatites.

Basement complex.

■ Areas of the studied pegmatites.

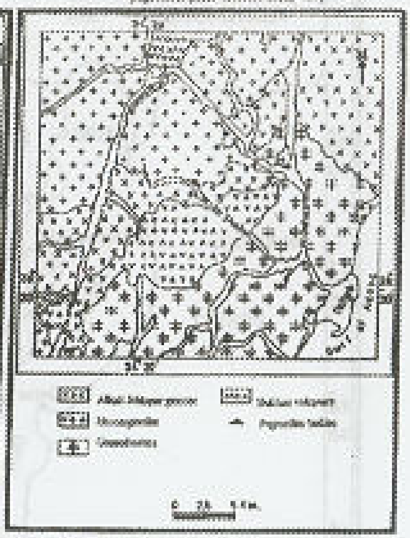


(Fig. 2A) Geological map of W. Mowaileh area and its related pegmatites (modified after Aly et al., 1984)

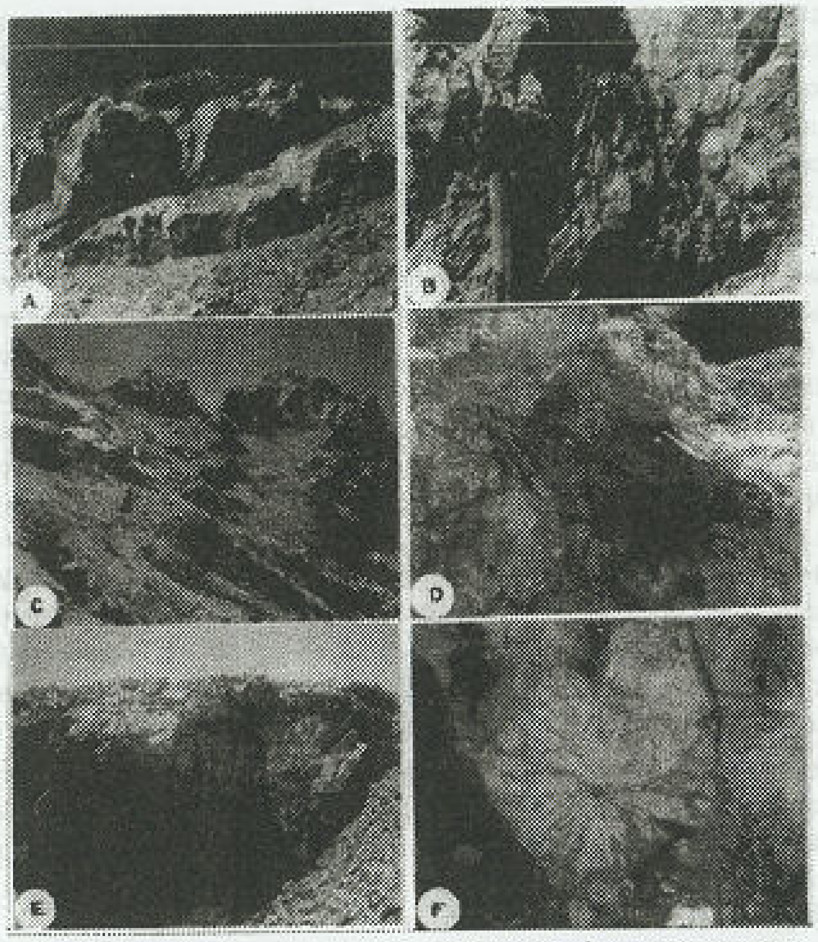


(Fig. 2B) Geological map of G. Abu Dob and its related pegmatites (after Ibrahim et al., 1997)

(Fig. 2C) Geological map of W. El Hudi granites and their related pegmatites (after Sagah et al., 1997)



(Fig. 2D) Geological map of W. Um Shala and W. Sabo and their related pegmatites (modified after EGSMA, 1992)



(Fig. 3)A: Simple pegmatite (arrow) hosted by alkali feldspar granite. W. Hawashia.

B) Pegmatitic lenses of alkali feldspar associated with a pocket of brown mica. (M) W. Hawashia.

C) Pegmatitic leaf-like alkali feldspar showing preferred orientation (arrows), G. Abu Dob.

D) A lens of pegmatitic mica hosted by monzogranite G. Abu Dob.

E) A pegmatitic body of quartz, W. El-Hudi.

F) Pegmatitic quartz exhibiting radial forms. W. El-Hudi.

PETROGRAPHY

Eastern Desert Pegmatites

Petrographically; the pegmatitic rocks of W. Hawashia could be classified as perthitic pegmatites, granitic pegmatites and pegmatitic mica. Perthitic pegmatite is composed mainly of megacrysts of perthite and antiperthite (Fig.

5A). Perthite crystals are strained and characterized by fracturing, undulose extinction and reaction rims occupied by fine crystals of albite as result of post-magmatic process (albitization). Granitic pegmatite is composed of megacrysts of patchy perthite, microcline and quartz (Fig. 5B) associated with few crystals of biotite. Pegmatitic mica also occurs as pockets of brown mica coloured by the high content of iron oxides.

Microscopic examination of Abu Dob pegmatites revealed that they occur as megacrysts of perthite and antiperthite of patchy type. Antiperthite is characterized by undulose extinction and enclosing very fine laths of albite which may be formed by post magmatic processes (Fig. 5C). Perthite crystals are characterized by their yellow amorphous nature which is responsible for the high radioactivity of Abu Dob perthitic pegmatite. Mica represents are the main mafic minerals in Abu Dob pegmatite. It is present as large flakes of length more than 20cm occurring in two main varieties; the first is phlogopite which is green in color and contains yellow radioactive material along cleavage planes (Fig. 5D), the second is muscovite with the reddish brown colour due to the high content of iron oxides and containing the radioactive material (Fig. 5E) while the third is pinkish brown manganophyllite.

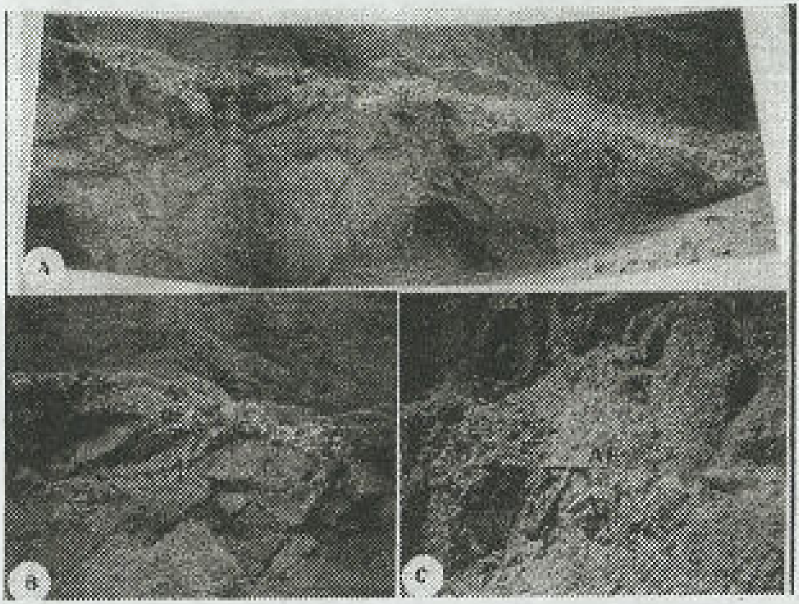
El Hudi pegmatites occur as monophasic bodies of pegmatitic feldspar or pegmatitic quartz and granitic pegmatite. Pegmatitic feldspars are characterized by their pale pink color and could be classified as perthitic pegmatite and granitic pegmatites. Perthitic pegmatite occurs as megacrysts of perthite of string and rod types; characterized by their undulose extinction (Fig. 6A).

The granitic pegmatite occurs as megacrysts of string perthite graphically intergrown with quartz (Fig. 6B) which are highly fractured and enclose secondary muscovite along the fractures. Few crystals of microcline and plagioclase are recorded.

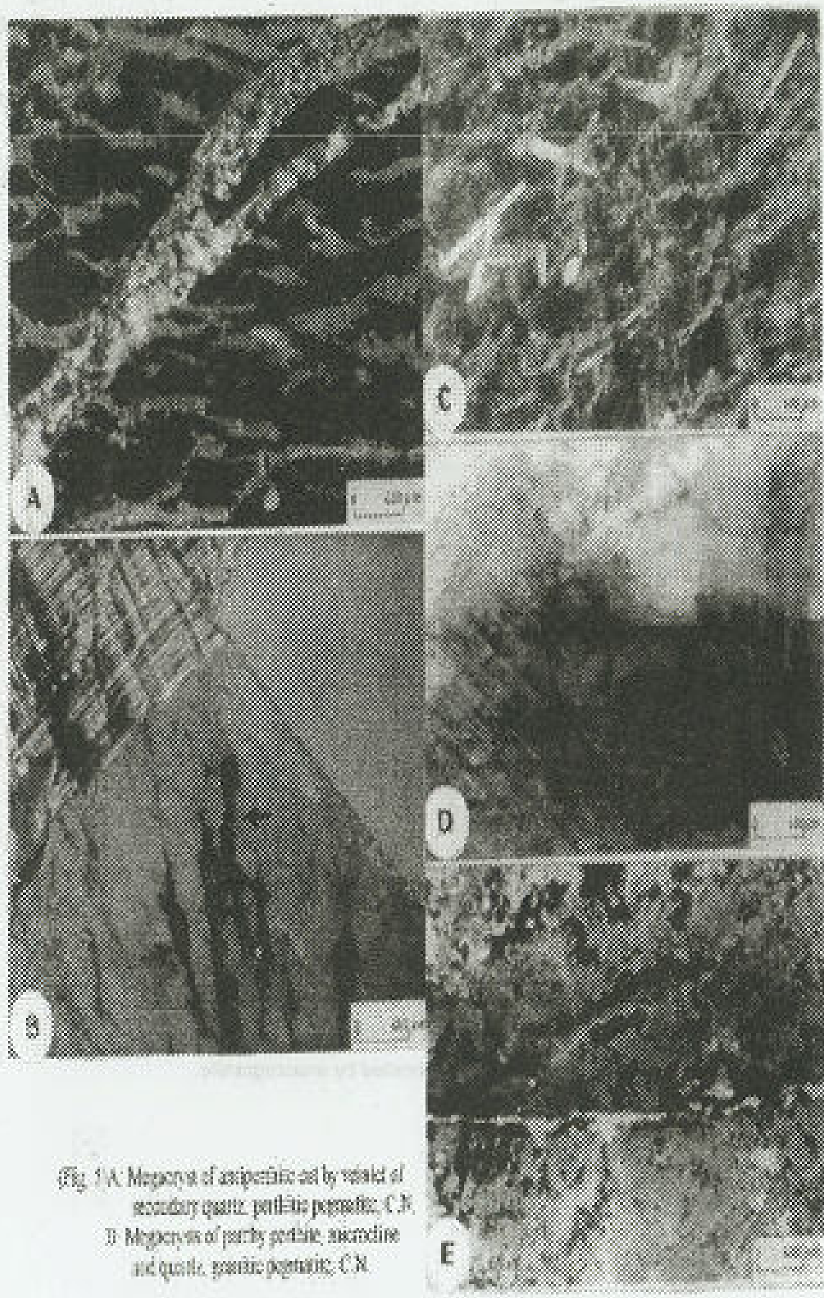
Sinai Pegmatites

The pegmatitic rocks of Um Shoki are of complex zoned type occurring as pegmatitic quartz and pegmatitic feldspars. The latter could be classified into perthitic pegmatite and granitic pegmatite according to their constituting minerals. Perthitic pegmatite is composed mainly of megacrysts of net type perthite (Fig. 6C) and antiperthite. They are stained by iron oxides and enclose minute crystals of quartz. Granitic pegmatite is composed mainly of megacrysts of perthite, antiperthite, and albite; measured about 2cm length. Antiperthite is graphically intergrown with quartz (Fig. 6D) and occasionally fractured forming cracks filled with secondary radioactive materials. Allanite represents the main accessory mineral occurring as euhedral crystals associating plagioclase and quartz.

In Wadi Dahab, the pegmatitic rocks are classified as perthitic pegmatite (mainly potash feldspar) and granitic pegmatite (granitic composition). Perthitic pegmatite is composed mainly of megacrysts of perthite and antiperthite characterized by cracks filled with iron oxides (Fig. 6E). Granitic pegmatite is composed mainly of megacrysts of perthite, antiperthite and albite (Fig. 6F) graphically intergrown with quartz forming graphic texture. Hydrous mafic minerals are mainly biotite with rare crystals of brown hornblende.

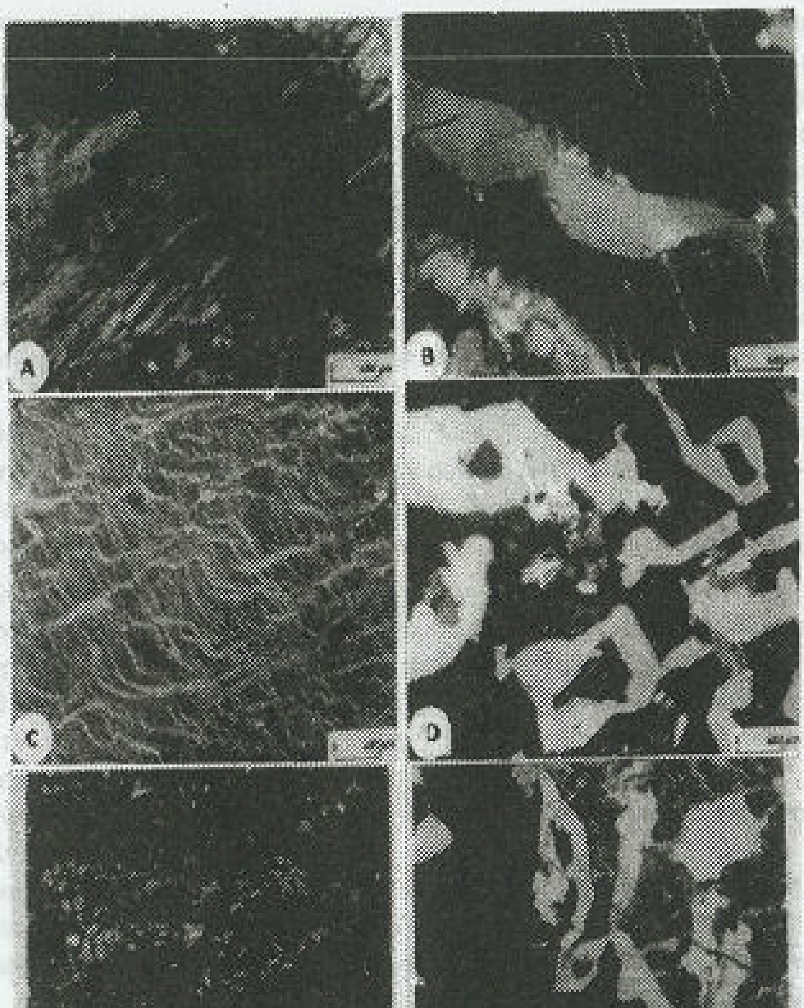


(Fig. 4)A: Panoramic view of Um Shoki pegmatitic body. Photo looking SE.
B: Zoned pegmatite showing outer alkali feldspar (AF) followed by quartz (Qz). W. Um Shoki.
C: Megacryst of alkali feldspar (AF) hosted by monzogranite.



(Fig. 5) A: Megacryst of antiperthite cut by veinlet of secondary quartz, perthitic pegmatite, C.N.
B: Megacryst of patchy perthite, microcline and quartz, graphic pegmatite, C.N.

C: Megacryst of antiperthite enclosing fine laths of plagioclase, perthitic pegmatite, C.N.
D: Megacryst of phlogopite associating orange radioactive material, pegmatitic mica, C.N.
E: Megacryst of muscovite enclosing radioactive material, pegmatitic mica, C.N.



(Fig. 6) A. Megacryst of string perthite showing undulose extinction, perthitic pegmatite. C.N.

B. Skeletal crystal of quartz graphically intergrown with string perthite, granitic pegmatite. C.N.

C. Megacryst of net perthite, perthitic pegmatite. C.N.

D. Megacryst of antiperthite showing graphic texture with quartz, granitic pegmatite. C.N.

E. Megacryst of antiperthite, cracked and filled with iron oxides, perthitic pegmatite. C.N.

F. Perthite (right crystal) and antiperthite (left crystal) megacrysts showing graphic texture with quartz, granitic pegmatite. C.N.

Geochemistry

Geochemistry of the pegmatitic rocks is based on chemical analysis data for both granitic pegmatites (14 samples) and their hosting granites (16 samples) besides mineral chemistry for both perthite (14 samples) and mica (15 samples) minerals. The analyses were preformed in the Nuclear Materials Authority Labs at Cairo.

Major oxides

Chemical analysis data of the major oxides for the studied granitic pegmatite, as listed in table 2, clarifying that the Hawashia granitic pegmatites are characterized by low silica content (68.86%- 69.21%) and high alumina (14.96%- 16.33%) and potash (8.25%- 8.76%) contents rather their hosting granites (Table 2). They are also characterized by relatively high differentiation index ranging between 92.75 and 94.59. El Hudi granitic pegmatite has relatively high silica (71.0%- 71.4%), alumina (13.76%-15.12%) and potash (6.82%- 8.95%) contents. They are characterized by high differentiation index ranging between 93.26 and 95.46. Orthoclase represents the highest norm value (with an average 50.86% for Hawashia and 47.82% for El Hudi) (Table 3).

Um Shoki granitic pegmatites are characterized by silica content ranging between 70.40% and 72.34% and high alumina content ranging between 14.00% and 14.32%. They are low in calcium content (0.35%-1.2%) and high in potassium content (6.14%- 7.89%). Their norm values revealed a high orthoclase content (average 40.85%) and low anorthite content (average 3.56%). Their differentiation indices range between 92.43 and 94.89 (Table 3). Those of Dahab are characterized by higher silica content ranging between 73.31% and 74.88% and lower alumina (13.02%-13.46%), potasium (3.92%-5.35%) and calcium (0.61%-1.08%) contents (Table 3). They are characterized by low normative orthoclase (average 26.53) and high albite norm values (average 32.15) rather than the other pegmatites. Their differentiation indices (D.I.) are relatively high ranging between 91.1 and 94.03.

Generally, the granitic pegmatites are characterized by high K_2O contents (average 6.72%) than their hosting granites (average 4.34%); especially the pegmatites of the Eastern Desert which are characterized by higher values (average 8.23%) than those of Sinai (average 5.60%). Total alkalies exhibits strong positive relation with Al_2O_3 in the pegmatitic rocks while in the granitic rocks, it shows irregular relation (nearly horizontal) (Fig. 7). It refers to the possibility that the pegmatites may have been enriched in alkalies by post-magmatic processes and it is mostly present in the form of potash feldspars.

Applying Shand's index diagram (Maniar and Piccoli, 1989) for the studied granitic pegmatites to identify their tectonic setting, it appears that all samples fall close to the metaluminous boundaries; within (POG) field (Fig. 8).

Trace elements

Analysis data of the trace elements of Eastern Desert pegmatites revea that Hawashia granitic pegmatites are characterized by high concentrations of Rb and Sr with averages 977ppm and 87 and low concentrations of Y, Zr, Nb and Pb than their hosting granite. Those of El Hudi granitic pegmatites showed that Ba and Sr are high with averages 378ppm and 317ppm respectively while Y, Zr, and Pb are relatively lower than their hosting granite (Tables 2&3). Their concentrations are normalized to chondrite values and plotted as spider diagram revealing that the Eastern Desert pegmatites are enriched in trace elements relative to chondrite. Th, U and Nb exhibit positive anomalies, while Zr and Pb exhibit negative anomalies. (Fig. 9).

The analysis data of trace elements of Sinai pegmatites show that Um Shoki granitic pegmatites have Ba, Rb, Sr and Zr concentrations lower than their hosting granite and the other concentrations appropriate those of the hosting granite. Those of Dahab granitic pegmatites clarified that they have Ba and Rb concentrations higher than their hosting granite (averages 126ppm and 288ppm respectively) (Tables 2&3). The chondrite-normalized patterns for Sinai pegmatites show that Th and U exhibit positive anomalies while Rb, Pb, Sr and Zr are strongly negative (Fig. 9).

Sr-Ba relation in the pegmatitic and granitic phases showed strong positive relation with correlation coefficient 0.73. Y shows also positive relation with both Zr, and Nb in the two phases with correlation coefficients 0.87 and 0.62 consequently but they show more limited mutual distribution in the pegmatitic phase with variable Y suggesting that the latter may be enriched in the post graniric phase. Th shows strong positive relation with U with correlation coefficient 0.71 exhibiting regular distribution in the pegmatitic phase and limited mutual distribution with U in granitic phase, referring to depletion of U in the pegmatitic phase and probable mobility to the hosting granite. Th show also mild positive relation with Nb ($r = 0.42$) with limited coherence in the pegmatitic phase referring to its depletion at the late stages (Fig. 9).

Rare Earth Elements Geochemistry

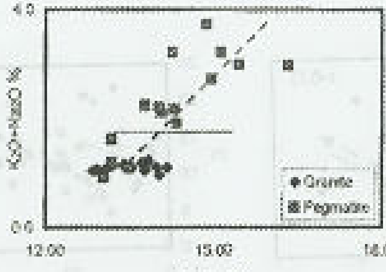
Ten samples representing the studied pegmatites and their hosting granites were analysed in the Egyptian National Research Center to determine eleven members of the rare earth elements concentrations Some geochemical parameters such as LREE/HREE ratio and Eu-anomaly are calculated (Table 4) as averages to throw light on the behavior of REEs in the studied pegmatites and their hosting granites.

The LREE/HREE ratio

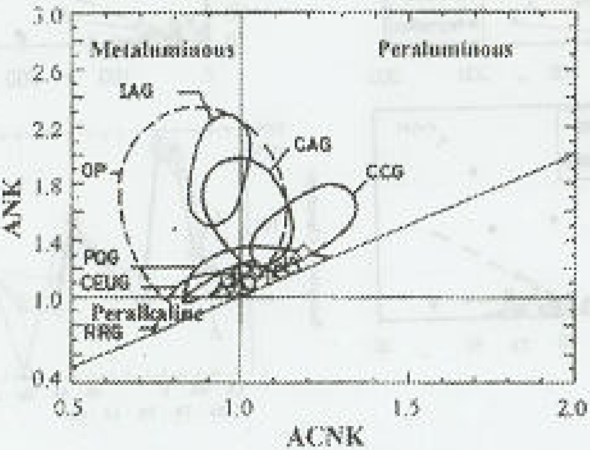
It is a measure of the fractionation of the LREEs relative to the HREEs. Granites appear to be relatively depleted in the total REE budget with an average of 202.29ppm, about 0.8 times the world–wide granite given by Hermann (1970). The studied granites are characterized by sever enrichment of the LREE (average 185.74ppm) over the HREE with an average LREE/HREE ratio equals 11.28. Pegmatites have average total REE content slightly lower than that of the granites with an average. 200.87ppm, lower LREE than the granite with an average 184.22ppm and HREE nearly the same as the granite with an average LREE/HREE ratio equals 11.07 (Table 4). The enrichment of LREEs relative to HREEs may be attributed to the presence of the accessory minerals such as monazite and allanite, which may strongly influence the REEs pattern due to their very high partition coefficient (Cathelineau, 1987).

Eu-anomaly

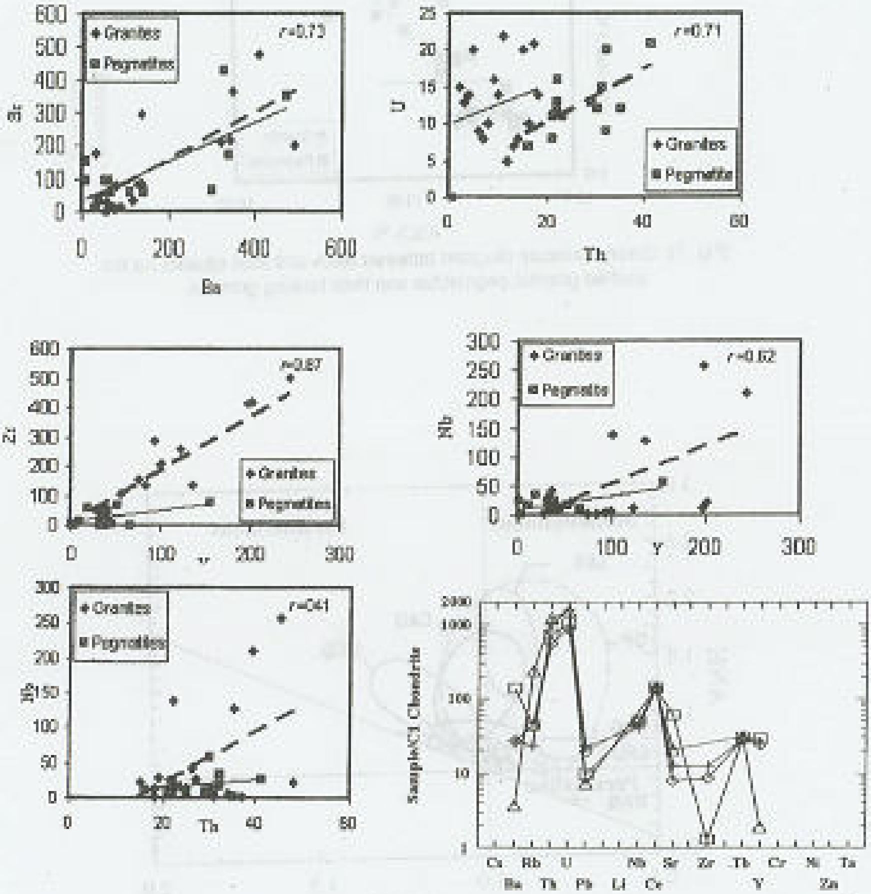
It is proposed by Henderson (1984) as $(Eu_{cn}) / \sqrt{(Sm_{cn}) (Gd_{cn})}$ where Eu, Sm and Gd are normalized by chondrite values to give the corresponding values Eu_{cn}, Sm_{cn}, and Gd_{cn}. Eu anomaly is chiefly controlled by the Ca-minerals such as anorthite, which has a minor effect on the other rare earth elements during crystallization from the melt. The Eu anomaly is due to the fact that Eu^{2+} is compatible in plagioclases in contrast with Eu^{3+}which is incompatible. Thus the removal of feldspars from a felsic melt by crystal fractionation or partial melting of a rock in which the feldspar is retained in the residue will give rise to negative Eu anomaly in the melt. The magnitude of the Eu anomaly decreases with increasing oxygen fugacity and temperature of the system (Henderson, 1984).
Granites contain low Eu (average 0.65ppm) but slightly higher than the pegmatites (Table 4). They are characterized by lower Eu electronegativity than the pegmatites with an exception for Hawashia where the anomalies of the granite and pegmatite are the same and characterized by the highest negativity which is attributed to the complete absence of plagioclase in the alkali-feldspar granite of Hawashia (Fig. 10). El Hudi granite is characterized by the lowest Eu anomaly due to its higher content of plagioclase. Pegmatites are characterized by lower Eu than the granites with an average 0.52ppm due to the absence of plagioclase (Fig. 10C).



(Fig. 7): Binary variation diagram between Al_2O_3 and total alkalies for the studied granitic pegmatites and their hosting granites.



(Fig. 8) : Shands index and tectonic setting of the studied granitic pegmatites (Maniar and Piccoli,1984). Δ= Hawashia, □= El Hadi,+= Um Shiki,○= Dabab



(Fig.9) A) Binary diagram of Bavs Sr D) Binary diagram of th vs U

B) Binary diagram of Y vs Zr E) Binary diagram of th vs Nb

C) Binary diagram of Y vs Nb F) Chondrite-normalized trace

Elements for the studied pegmatites (Chondrite value after Boynton, 1984) Symbols as in Fig 8

Table 2: Chemical analysis data of major oxides (Wt%) and trace elements (ppm) of the granitic rocks

Sample	HG3	HG4	HG6	HG7	HG8	HG9	EG5	EG9	EG10	UG4	UG7	UG1	UG3	UG8	UG10	DG2	DG4
SiO_2	75.00	75.07	74.10	75.00	74.74	74.88	73.70	73.96	74.00	74.46	74.38	74.80	72.39	74.71	74.68	72.39	72.49
TiO_2	0.10	0.10	0.10	0.10	0.13	0.10	0.08	0.07	0.16	0.13	0.10	0.06	0.15	0.11	0.09	0.19	0.20
Al_2O_3	13.70	13.82	13.80	13.19	13.10	13.41	13.01	12.82	12.89	13.17	13.96	12.91	14.01	13.39	13.52	14.15	13.76
Fe_2O_3	0.31	0.37	0.32	0.50	0.71	0.88	1.72	1.38	0.52	1.01	0.90	1.02	1.57	0.75	1.06	1.60	1.65
FeO	0.45	0.62	0.45	0.36	0.41	0.47	0.92	0.78	1.41	0.37	0.31	0.41	0.33	0.24	0.29	0.60	0.70
MnO	0.02	0.03	0.02	0.05	0.03	0.05	0.03	0.04	0.07	0.04	0.03	0.03	0.06	0.04	0.06	0.06	0.09
MgO	0.09	0.21	0.18	0.29	0.21	0.28	0.42	0.86	0.57	0.47	0.28	0.21	0.85	0.29	0.31	0.55	0.50
CaO	0.51	0.36	0.51	0.50	0.75	0.68	0.98	1.07	1.08	0.73	0.75	0.95	0.99	0.81	1.08	1.70	1.73
Na_2O	4.10	3.87	4.00	4.02	4.11	3.88	3.96	3.98	4.09	3.82	4.08	4.01	3.71	3.98	3.65	3.64	3.84
K_2O	4.85	4.72	4.85	4.65	4.52	4.38	4.03	4.15	4.28	4.31	4.52	4.27	3.57	4.61	4.00	4.02	4.04
P_2O_5	0.09	0.12	0.10	0.17	0.12	0.10	0.07	0.06	0.12	0.17	0.07	0.18	0.18	0.09	0.09	0.08	0.13
L.O.I	0.67	0.62	0.62	0.98	1.01	0.71	0.90	0.78	0.86	1.21	0.50	1.03	2.00	0.83	1.04	0.92	0.76
Ba	54	57	55	55	407	347	320	340	135	128	492	116	78	31	139	88	76
Rb	599	598	477	710	94	84	19	20	45	94	169	52	178	163	128	210	90
Sr	2	2	29	2	478	365	210	217	285	85	200	34	80	179	83	16	8
Y	244	100	136	197	98	74	92	198	83	27	202	31	33	122	31	55	35
Zr	504	208	135	197	207	156	290	413	135	55	421	23	51	268	42	109	68
Nb	211	138	128	257	7	2	6	12	2	2	22	26	13	13	29	23	43
Pb	51	42	48	54	47	39	62	46	51	30	37	45	33	34	36	44	50
Th	39	22	36	45	25	18	34	30	31	37	15	27	18	25	19	48	26
U	15	13	14	20	9	8	10	16	14	22	5	7	8	20	10	21	14

Table 3: Chemical analysis data of major oxides (Wt%) and trace elements (ppm) of the pegmatitic rocks.

Sample	HK1	HK3	HK8	EK2	EK3	EK4	UK2	UK3	UK4	UK5	DK1	DK2	DK3	DK5
SiO_2	68.75	69.21	68.88	71.40	71.08	71.00	71.83	72.34	70.40	70.75	74.88	74.22	74.06	73.31
TiO_2	0.06	0.08	0.06	0.07	0.01	0.05	0.02	0.04	0.06	0.06	0.09	0.11	0.15	0.05
Al_2O_3	16.33	14.86	15.44	15.12	14.87	13.76	14.25	14.05	14.32	14.00	13.46	13.02	13.17	13.16
Fe_2O_3	1.05	0.89	0.94	1.00	1.00	0.52	1.21	1.88	0.85	0.77	0.74	0.95	2.81	0.53
FeO	0.60	0.56	0.87	0.20	0.23	0.36	0.41	0.87	0.43	0.54	0.51	0.52	0.41	0.29
MnO	0.3	0.08	0.12	0.03	0.37	0.05	0.37	0.25	0.05	0.07	0.03	0.04	0.04	0.05
MgO	0.42	0.28	0.38	0.01	0.04	0.43	0.04	0.09	0.36	0.44	0.27	0.35	0.19	0.29
CaO	0.31	0.87	0.54	0.26	0.47	1.10	0.35	0.53	1.20	1.02	0.86	1.08	0.81	0.75
Na_2O	2.77	3.1	2.80	2.63	2.40	3.06	2.45	2.02	3.30	3.09	4.00	4.27	3.42	3.32
K_2O	8.25	8.45	8.76	8.13	8.95	8.82	7.89	8.14	6.30	6.78	4.35	3.92	4.04	5.35
P_2O_5	0.01	0.07	0.04	0.01	0.01	0.07	0.01	0.04	0.07	0.10	0.11	0.16	0.10	0.09
L.O.I	1.08	1.43	1.22	0.99	0.42	1.13	1.06	1.04	1.10	1.00	0.70	1.23	0.92	1.15
Ba	9	82	9	338	324	473	64	53	39	140	108	66	298	30
Rb	995	1002	935	204	100	57	55	42	39	225	213	100	464	375
Sr	151	16	85	172	429	351	91	93	32	57	60	57	64	12
Y	3	155	19	52	45	35	40	35	10	33	39	38	2	66
Zr	2	79	60	69	5	2	47	51	15	2	41	33	5	2
Nb	2	58	34	18	12	16	10	12	18	9	26	12	24	10
Pb	18	13	14	34	24	21	57	55	17	14	38	48	27	25
Th	35	30	32	32	21	25	28	31	22	21	41	16	22	22
U	12	12	9	20	8	11	13	15	13	11	21	7	18	12

Petrogenetic modelling

Geochemical modeling using the rare earth elements have been successfully used to interpretate the petrogenesis and origin of igneous rocks by many authors such as Neuman et al (1954), Schilling & Winchester (1967), Gast (1968) and Shaw (1970). Calculations are based on bulk partition coefficient (D_i) for each element (i) which in turn is based on the partition coefficients (Kds) of this element in the minerals constituting the rock. Partition coefficients of some rare earths in quartz, alkali-feldspar, plagioclase and biotite of the acidic rocks as quoted by Schnetzler and Philpotts (1970), Arth (1976), Hanson (1980) and Nash and Crecraft (1985) are used in modeling for the studied pegmatites (Table 5). The fractional crystallization model is applied for Hawashia, Abu Dob, Um Shoki and Dahab pegmatites and the partial melting model is used for El Hudi pegmatite. Using the melt derived from the lower crust with modal mineralogy 70% plagioclase, 15% orthopyroxene and 15% clinopyroxene (McGuire and Stern, 1993) as a parent liquid; the concentration of REEs in the residual liquids derived by 35% fractionation and 30% partial melting are calculated.

a) Fractional crystallization model

The fractional crystallization model is calculated for Hawashia, Abu Dob, Um Shoki and Dahab pegmatites using the equation of Neuman et al. (1954); $C^i_{liq} = C^i_O F^{Di-1}$ where;

The calculated concentrations of the rare earths in the residual liquid with fractional crystallization degree 35% are listed in (Table 6) giving results appropriating those for the studied pegmatites.

b) Partial melting model

The foundation of this model was first laid down by Schilling & Winchester (1967). He used the equation $C^i_{liq} = C^i_O / F + D_i (1-F)$ with partial melting degree assumed as 30%. This model is simply used to identify origin of El Hudi pegmatites which is formed by anatectic processes. The calculated concentrations of the rare earths in the residual liquid with partial melting degree 30% are listed in (Table 7) which is nearly similar to their concentrations in the studied pegmatite.

Table 4: Average REE concentrations (ppm) and some geochemical parameters in the granitc and egmatitic phases.

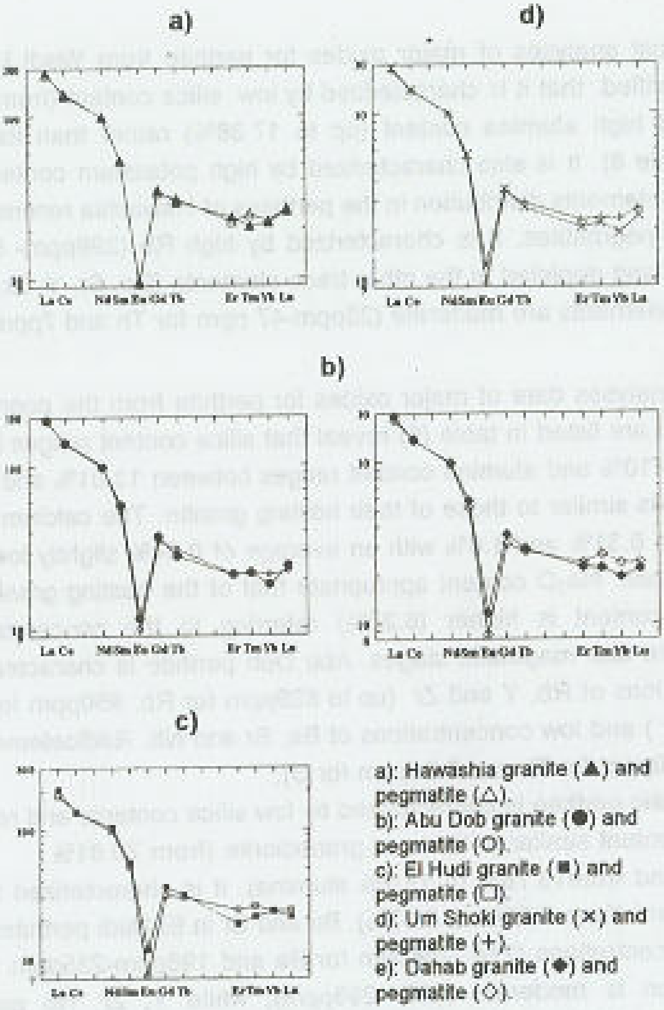
Rock	Granite	Pegmatite
Sample	Average	Average
La	45.81	43.99
Ce	83.9	85.59
Nd	46.88	46.07
Sm	8.57	8.06
Eu	0.65	0.52
Gd	7.31	6.69
Tb	1.08	1.11
Er	3.5	3.75
Tm	0.54	0.62
Yb	3.45	3.85
Lu	0.59	0.62
□REE	202.29	200.86
□LREE	185.74	184.22
□HREE	16.48	16.64
LREE/HREE	11.28	11.07
Gd/Yb	1.67	1.41
Eu-anomaly	0.242	0.218

Chondrite normalization according to Boynton (1984).

Table 5:REEs partition coefficients (Kds) in acidic rocks used for geochemical modelling of the studied pegmatites.

Element	Quartz	K.feldspar	Plagioclase	Biotite
La	0.015	0.05	0.32	0.28
Ce	0.014	0.044	0.27	0.32
Nd	0.016	0.025	0.21	0.29
Sm	0.014	0.018	0.13	0.26
Eu	0.056	1.13	2.15	0.24
Gd	....	0.011	0.97	0.28
Tb	....	....	....	....
Er	....	....	....	....
Tm	....	....	....	....
Yb	0.017	0.012	0.049	0.44
Lu	0.014	....	....	....

Kds values are from Schnetzler and Philpotts (1970), Arth (1976) Hanson (1980) and Nash& Crecraft (1985).



(Fig. 10):Chondrite-normalized REE pattern of the studied granites and pegmatites. (Normalization according to Boynton, 1984).

C^{i}_{liq} = Concentration of an element (i) in the liquid .

C^{i}_{O} = Concentration of an element (i) in the source prior to melting.

F = Fractional crystalization degree (assumed as 30%).

D_i = Bulk partition coefficient

MINERAL CHEMISTRY

Wet chemical analyses were performed for the pegmatitic minerals comprising both the perthitic pegmatite and the pegmatitic mica to determine their major oxides contents. Concentrations of trace elements were determined by X-ray fluorescence (XRF).

Perthite

The chemical analyses of major oxides for perthite from Wadi Hawashia pegmatites clarified that it is characterized by low silica content (from 67.63% to 69.1%) and high alumina content (up to 17.36%) rather than its hosting granite (Table 8). It is also characterized by high potassium content (up to 8.10%). Trace elements distribution in the perthites of Hawashia resembles that of the granitic pegmatites. It is characterized by high Rb (399ppm- 574ppm) concentrations and depleted in the other trace elements (Ba, Sr, Y, Zr, Nb and Pb). The radioelements are moderate (28ppm-47 ppm for Th and 7ppm-22ppm for U)

Chemical analyses data of major oxides for perthite from the pegmatite of Gabal Abu Dob are listed in table (8) reveal that silica content ranges between 71.21% and 74.10% and alumina content ranges between 13.01% and 14.91% with an averages similar to those of their hosting granite. The calcium content ranges between 0.31% and 1.6% with an average of 0.84% slightly lower than the hosting granite. Na_2O content appropriate that of the hosting granite while average K_2O content is higher (6.25%) referring to the concentration of potassium in the late magmatic stages. Abu Dob perthite is characterized by high concentrations of Rb, Y and Zr (up to 839ppm for Rb, 950ppm for Y and 1300ppm for Zr) and low concentrations of Ba, Sr and Nb. Radioelements are moderate (31-39ppm for Th and 8-30ppm for U).

El Hudi pegmatitic perthite is characterized by low silica contents and relatively high alumina content similar to those of granodiorite (from 70.81% to 71.63% silica and from13.76% to 15.2% alumina). It is characterized by high potassium content (from 7.96% to 8.57%). Ba and Sr in El Hudi perthites attain the highest concentrations (214 -254ppm for Ba and 198ppm-235ppm for Sr). Rb concentration is moderate (215 -293ppm), while Y, Zr, Nb and Pb concentrations are relatively low. Radioelements concentrations are moderate (29ppm-30ppm for Th and 18ppm-20ppm for U).

The perthites from the pegmatites of Wadi Um Shoki are characterized by silica content ranging between 70.81% and 71.11% and alumina content ranges between 14.33% and 14.51%. K_2O content is high ranging between 7.46% and 7.65% (Table 8). Trace elements distribution in Um Shoki perthites is characterized by the highest Pb concentration (up to 48ppm) and lowest Ba, Rb, Sr, Y and Zr concentrations which are also lower than their hosting granites (Table 2).

Table 6 : The Estimated REEs concentrations from fractional crystallization for the petrogenesis interpretation of the studied pegmatites model.

Element	Parent Comp.	Hawashia		Abu Dob		Um Shoki		Dahab	
		F=35%	Analysis	F=35%	Analysis	F=35%	Analysis	F=35%	Analysis
La	16	42.96	43.91	43.38	44.91	41.24	44.01	42.39	43.09
Ce	33	89.76	85.93	90.03	86.01	86.24	86.03	87.97	85.01
Nd	16	43.88	46.31	44.53	46.91	42.7	46.51	43.42	45.61
Sm	3.5	9.67	8.11	9.81	8.01	9.55	8.13	9.64	8.01
Eu	1.1	1.11	0.56	0.96	0.57	1.27	0.55	1.44	0.49
Gd	......	......	6.91	......	7.01	......	6.92	......	6.31
Tb	......	......	1.16	......	1.14	......	1.08	......	1.04
Er	......	......	3.65	......	3.51	......	3.75	......	3.91
Tm	......	......	0.63	......	0.56	......	0.6	......	0.68
Yb	2.2	6.05	3.81	6.21	3.95	6.11	3.92	6.09	3.96
Lu	......	......	0.67	......	0.57	......	0.67	......	0.6

F is fractional crystallization degree

Table 7 : The Estimated REEs concentrations from partial melting model for El Hudi pegmatite.

Element	Parent Comp.	El Hudi	
		F=30%	Analysis
La	16	48.37	44.02
Ce	33	100.61	84.97
Nd	16	49.96	45.01
Sm	3.5	11	8.02
Eu	1.1	1.4	0.43
Gd	......	......	6.3
Tb	......	......	1.11
Er	......	......	3.91
Tm	......	......	0.64
Yb	2.2	6.99	3.95
Lu	......	......	0.6

F is partial melting degree

Table 9: Chemical analysis data of major oxides (Wt%) and trace elements (ppm) of perthites

Peg. body	Hawashia			Abu Dob					El Hudi		Um Shoki		Dahab	
Sample	HK2	HK4	HK5	AK1	AK2	AK3	AK4	Ak5	EK1	Ek5	UK1	UK6	DK4	DK8
SiO2	69.1	67.63	69.00	71.21	72.02	74.10	71.64	72.85	70.81	71.63	71.11	70.81	72.49	71.82
TiO2	0.09	0.05	0.05	0.52	0.04	0.10	0.02	0.06	0.01	0.04	0.12	0.14	0.14	0.09
Al2O3	16.36	17.36	16.03	13.01	13.51	13.08	14.91	13.34	15.20	14.68	14.33	14.51	13.62	13.87
Fe2O3	0.90	1.00	1.04	1.72	1.10	0.46	0.72	1.42	0.31	0.68	0.61	0.78	0.82	1.29
FeO	0.63	0.50	0.26	1.83	0.36	0.43	0.35	0.76	0.11	0.47	0.31	0.47	0.51	0.63
MnO	0.72	0.32	0.65	0.06	0.53	0.05	0.02	0.42	0.02	0.03	0.04	0.05	0.03	0.03
MgO	0.25	0.29	0.28	1.09	0.02	0.32	0.31	0.04	0.07	0.05	0.29	0.18	0.23	0.18
CaO	0.28	0.36	0.28	1.13	0.31	0.76	1.60	0.41	0.51	0.48	0.78	0.66	0.64	0.41
Na2O	2.95	2.75	2.42	4.21	2.40	4.31	2.15	3.11	3.31	3.34	3.62	3.43	3.45	3.61
K2O	7.62	8.1	7.75	3.95	8.09	5.49	7.01	6.69	8.57	7.96	7.65	7.46	6.82	7.25
P2O5	nd	nd	nd	0.12	nd	0.12	0.06	0.11	nd	0.02	0.17	0.15	0.12	0.08
L.O.I	0.98	1.14	1.45	1.13	1.41	0.75	0.95	0.78	0.64	0.59	1.01	1.26	0.88	0.76
Ba	12	9	10	53	96	103	91	98	214	254	9	26	8	12
Rb	399	574	452	nd	839	95	693	635	283	215	12	17	153	131
Sr	62	6	nd	nd	16	115	18	24	235	198	Nd	4	64	56
Y	78	7	nd	950	30	357	95	65	33	28	15	19	25	18
Zr	171	11	nd	1300	130	1100	2	365	10	14	3	32	7	12
Nb	15	10	4	nd	26	29	4	24	nd	2	25	18	25	26
Pb	46	28	18	29	31	30	22	26	32	34	48	36	44	37
Th	28	47	32	39	42	31	37	32	30	29	32	24	23	17
U	10	22	7	30	18	8	17	14	23	18	19	13	8	6

Table 9 : Chemical analysis data of major oxides (Wt%) and trace elements (Wt%) of mica minerals

Peg.body	Hawashia				Abu Dob				Um Shoki			Dahab			
Mineral	Mus	Mus	Mang	Bio	Mus	Phl	Mus	Mang	Bio	Bio	Bio	Mus	Bio	Bio	Mus
Sample	HM1	HM2	HM3	HM4	AM1	AM2	AM3	AM4	UM1	UM2	UM3	DM1	DM2	DM3	DM4
SiO2	45.20	46.04	39.64	42.09	53.41	51.92	44.02	41.93	36.72	37.00	37.24	45.48	37.21	37.05	46.14
TiO2	0.22	0.17	0.42	2.61	0.1	0.04	0.23	0.65	2.78	2.52	1.91	0.22	3.21	3.15	0.19
Al2O3	34.95	36.05	18.45	25.92	27.64	16.99	35.32	17.35	15.60	16.01	14.89	35.85	14.90	14.74	32.07
Fe2O3	3.96	4.25	12.35	11.75	3.11	1.21	7.01	1.05	11.76	12.14	10.98	4.13	12.94	14.02	5.42
FeO	1.00	1.23	2.35	1.56	1.1	2.73	1.07	2.16	16.61	17.02	18.13	1.13	16.85	15.83	2.16
MnO	0.08	0.20	0.02	0.13	0.2	0.21	0.16	0.02	0.27	0.31	0.44	0.10	0.32	0.25	0.40
MgO	0.06	0.08	11.25	4.05	0.12	10.26	0.10	20.87	4.00	4.11	3.85	0.10	3.59	3.66	0.10
CaO	0.02	0.03	0.02	0.04	0.04	0.05	0.06	0.03	0.06	0.02	0.04	0.04	0.05	0.05	0.03
Na2O	1.00	0.75	0.81	0.11	0.85	0.92	0.65	0.24	0.14	0.20	0.17	0.82	0.22	0.28	0.97
K2O	10.72	9.42	10.68	9.23	10.46	12.54	10.02	10.86	10.05	9.57	9.41	9.66	8.52	8.67	10.21
L.O.I	2.54	1.58	3.61	2.3	2.63	2.59	1.6	4.72	2.02	1.00	2.70	2.46	2.12	2.26	2.11
Ba	844	803	654	901	63	81	96	79	110	87	134	84	97	128	82
Rb	172	182	197	170	212	1238	201	1127	122	74	95	186	107	88	178
Sr	34	30	29	37	35	19	37	21	41	37	42	38	46	49	37
Y	38	39	42	34	6	14	9	12	nd	38	31	24	nd	6	31
Zr	78	82	127	78	24	43	29	37	65	45	68	65	48	45	72
Nb	923	45	39	1037	14	23	19	22	12	18	nd	17	6	nd	18
Th	54	48	43	50	28	38	33	38	34	28	42	26	21	18	20
U	82	24	18	120	23	28	24	26	14	11	16	14	8	7	11

Perthites of Wadi Dahab pegmatite are characterized by relatively high silica (from 71.82% to 72.49%) and potassium (from 6.82% to 7.25%) contents. Alumina content ranges from 13.62% to 13.87% appropriating that of the hosting granites (Table 8). Concentrations of trace elements in Dahab perthites appropriate those of Um Shoki except for Rb and Sr which attain higher value (131ppm-153ppm for Rb and 56ppm-64ppm for Sr) and U which is intensively depleted (6ppm-8ppm).

Plotting of the norm values of perthite minerals from the studied perthitic pegmatites on Qz-Ab-Or ternary diagram (Tuttle and Bowen, 1958 and Winkler, 1979) clarified that all of them fall in the field of potassic feldspar (Fig. 11).

Mica Minerals

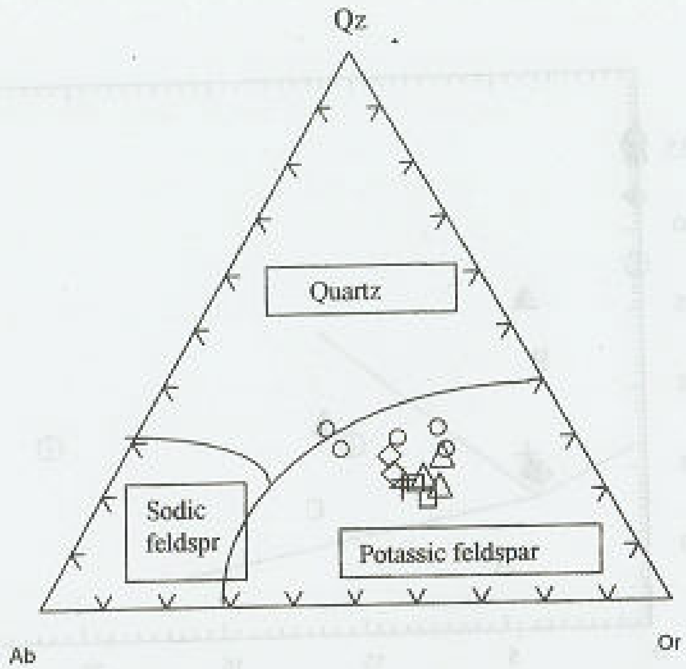
Mica minerals of Wadi Hawashia were identified by XRD technique as muscovite, manganophyllite and biotite. Muscovite is characterized by higher silica (with an average 45.62%) and alumina (with an average 35.5%) contents and lower iron oxides and magnesium contents than manganophyllite and biotite. Manganophyllite is characterized by high magnesium content (11.25%) (Table 9)

Mica minerals of Gabal Abu Dob are mainly muscovite phlogopite and manganophyllite. Muscovite is characterized by higher alumina content rather than manganophyllite with an average 31.58% and very low magnesium content. Manganophyllite is characterized by very high magnesium content with an average 15.62% (Table 9).

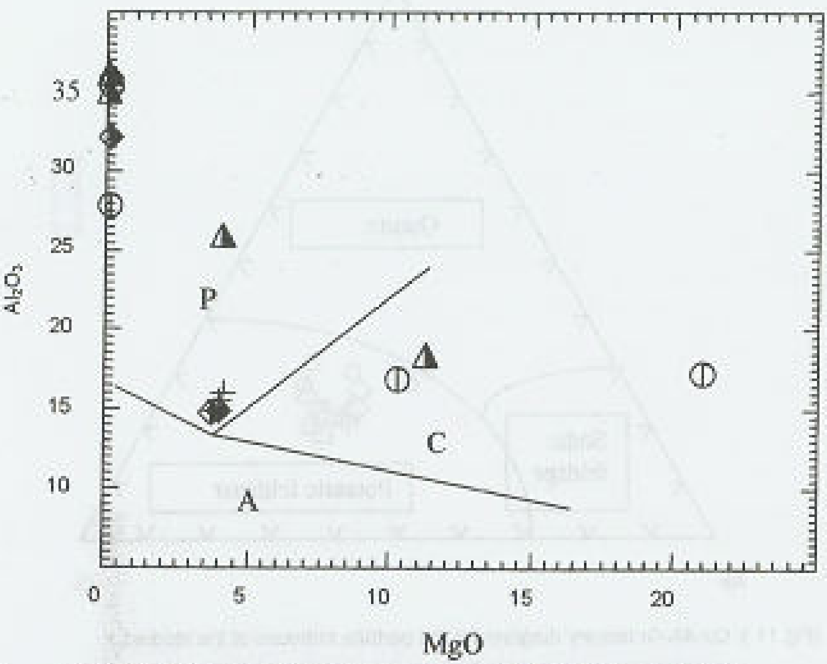
Mica minerals of Wadi Um Shoki are mainly biotite characterized by very low silica content ranging between 36.72% and 37.24% and relatively high alumina (ranging between 14.89% and 16.01%) and iron (from 10.98% to 12.14% for Fe_2O_3 and from 16.61% to 18.13% for FeO) contents. Potassium content is very high ranging between 9.41% and 10.05% (Table 9).

Mica minerals of Wadi Dahab are mainly muscovite and biotite. Muscovite is characterized by high silica (from 45.46% to 46.14%) and alumina (from 32.07 to 35.85%) contents. Biotite is characterized by high iron oxides contents (from 12.94% to 14.02% for Fe_2O_3 and from 15.83% to 16.85% for FeO) and higher magnesium contents (from 3.59 % to 3.66%) (Table 9).

On the other hand their plotting on biotite discrimination diagram of Abdel Rahman (1994) shows that the mica minerals of Wadi Hawashia and Gabal Abu Dob are restricted to peraluminous (P) and calc-alkaline (C) fields. Those of Wadi Um Shoki and Wadi Dahab fall in peraluminous field (Fig. 12).



(Fig.11): Qz-Ab-Or ternary diagram for the perthite minerals of the studied pegmatites. (Tuttle and Bowen, 1958; Winkler, 1979).
△ = Hawashia perthite, ○ = Abu Dob perthite, El Hudi perthite ;
+ = Um Shoki perthite, ◇ = Dahab mica



(Fig. 12) : Plotting of the mica minerals on biotite discrimination diagram. (after Abdel Rahman, 1994). P= Peraluminous, C=Calc-alkaline, A =Alkaline △= Hawashia mica, ○= Abu Dob mica, ✱= Um Shoki mica, ◇= Dahab mica

DISCUSSION

Few publications concerning the petrogenesis of pegmatites in the Eastern Desert and South Sinai have been done (El Sheshtawy et al., 1988; Essawy *et al*; 1997; El Aassy *et al.*, 1997; El Dougdoug *et al.*, 1997, Salem *et* al, 1998 and Heikal *et al.*, 2001). These considered pegmatites to be attributed to either 1) magmatic differentiation of volatile enriched granitic magma, genetically related to nearby granitic intrusions or 2) differentiated melt of lower crust materials in combination with metasomatism associated with volatile input.

The studied simple unzoned pegmatites (e.g. Hawashia, El Hudi and Dahab) and complex zoned types (e.g. Abu Dob and Um Shoki) show textural and mineralogical variation that defined concentric zones of non-uniform thickness as in Abu Dob and Um Shoki pegmatites. The presence of graphic intergrowths near the marginal parts of both zoned and unzoned pegmatites under consideration indicate pegmatitic melts that are close to the primary field of crystallization of a sodic plagioclase (Cerny, 1982). The abnormal giant crystals of perthite and micas must have crystallized directly from volatile-rich pegmatitic liquid (Cerny, 1982). The effect of water presence on melting relations in the granitic system of the studied pegmatites and their hosting granites is well demonstrated indicating potassic-rich and quartz-poor rocks. This is attributed to K-metasomatism. In addition, the melts generated by muscovite to have certain chemical characteristics i.e.: 1) they tend to be relatively high in K with K/Na atomic ratio >1; 2) and they are strongly peraluminous.

The REEs patterns for ten samples of the studied pegmatites and their hosting granitoids are almost parallel but with HREEs depletion in the latter. The Eu defficiency is striking in both the granitic rocks (average 0.24) and the pegmatitic rocks (average 0.22). It is attributed to fractionation of plagioclase and perthite. The chondrite lower ratio (Gd/Yb)cn with an average 1.67 in the hosting granites and 1.41 in pegmatites imply less fractionation and clear effect of micas in the granitic melt system (Stone, 1992).

REEs modeling for El Hudi pegmatites and their hosting granitoids is based on petrogenetic constrains calculated using the crustal derived melt as a source composition and Kds as proposed by Schnetzler and Philpotts (1970), Arth (1976), Hanson (1980) and Nash and Crecraft, (1985). Using the composition of the melt derived by anatexis of the lower crust as a parent liquid, the concentration of REEs in the residual liquid derived by 30% partial melting degree would give a pattern similar to the observed REE patterns of the studied rocks. On the other hand REE modeling for Hawashia, Abu Dob, Um Shoki and Dahab pegmatites is closely related to the fractional crystallization model in which the calculated concentrations of REE in the residual liquid with fractional crystallization degree (35%), giving rise to results similar to that for the studied pegmatites.

In summary, the studied pegmatites and their hosting granitoids are more likely to originate from partial melting of lower crust residual rocks (e.g. El Hudi) or by fractional crystallization that imparted on alkaline character of the magma. Both are followed by mantle metasomatism. A combination of anatexis and magmatic process are well recognized for the studied pegmatites.

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نشأة أجسام بيجماتيتية مختارة من الصحراء الشرقية وسيناء- مصر

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يتناول البحث نشأة صخور البجماتيت لأجسام مختارة من الصحراء الشرقية وسيناء ، منها البسيط مثل حواشية ، الهودى ودهب ومنها المعقد(متعدد النطاقات) مثل أبو دب و أم شوكى.
أوضحت الدراسة البتروجرافية أن هذة الصخور إما أنها جرانيتية تتكون من فلسبارات قلوية وكوارتز+ معادن الميكا (ماسكوفيت،بيوتيت، فلوجوبيت ومانجنوفيلليت) أو أنها تتكون أساسا من الفلسبارات القلوية. يمثل الألنيت و الزركون و الأبتيت و الكاستيريت أهم المعادن المساعدة هذا بالإضافة إلى بعض المعادن المشعة مثل اليورانوفين.
كما أوضحت التحاليل الكيميائية أن معظم هذة الصخور تتراوح من شحيح الألومينا إلى متوسط الألومينا مع إرتفاع نسبة العناصر القلوية وإنخفاض نسبة الكالسيوم ، ويتميز معدن المنجنوفيلليت بارتفاع نسبة الماغنسيوم و الألومينا. وبدراسة العناصر الشحيحة لتوضيح نظام النشأة لكل جسم اتضح أن نظام التبلور التمايزى هو الأنسب لكل من حواشية و أبو دب و أم شوكى و دهب وأن الصهر الجزئى يوافق بجماتيت الهودى. هكذا توضح الدراسة أن صخور البجماتيت والصخور المضيفة لها تكونت من المجما بنظام التبلور التمايزى و الصهر الجزئى متبوعة ببعض التحولات.