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ORIGIN AND TECTONIC ENVIRNMENT OF THE PAN-AFRICAN ROCKS OF ABU EL TIYUR AREA, EASTERN DESERT, EGYPT

BY

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الأصـل والبيئـة التكتونيـة لصخـور البـان أفريقي بمنطقة أبو الطيـور الصحـــراء الشرقيـــة - مصـــر

باهر القليوبي وعبد الغني رجب وزينهم الألفي

يتناول البحث جيوكيميائية وأصل صخور البان أفريقي المكونة لمنطقة أبـو الطيور والتي تغطى مساحة ٨٢٥ كيلو متر مربـع في وسط الصحراء الشرقية بمصر. تظهر الخواص البتروكيميائيـة لصخور السبيلليت والديابيز الأسبيلليتي نوع صهير ثيوليتي يستنتج منه أنها تكون جزء من تتابع أوفيوليت لبيئة حيود منتصف المحيط التكتونية. وتعطى الدراسة البتروكيميائيـة لصخور الأقواس المجهانية ان مصدر الصهير كان كلسي - قلوي منخفض البوتاسيوم مشابه للبيئة التكتونيـة لأقواس الجزر الأنسيهاتية. ومن الناحية الجيوكيميائية تعتبر جرانيتويدات الإلتحام المتأخرة ذات خواص كلسي - قلوية.

Key Words : Origin, Tectonic, Pan African, Eastern Desert

ABSTRACT

The present paper deals with the geochemistry and origin of the Pan - African basement rocks, which covers about 825 km^2 North of Abu El Tiyur area, in the Central Eastern Desert of Egypt.

The petrochemical character of the spilitics and spilitic diabase, under consideration, exhibits a tholeiitic magma type suggesting that they form a part of the ophiolitic assemblage of Mid - oceanic ridge geotectonic environment.

The petrochemical study of the magmatic arc suite reveals that their source is a low - potassium calc alkaline type similar to that of ensimatic island arc environments.

Geochemically the late collision granitoids are of calc - alkaline character.

GEOLOGY OF THE AREA

The geology of Abu El-Tiyur area was published elsewhere (Ragab et al, 1993) [1]. A brief summary will be however given here. The Abu El Tiyur area is essentially covered by Pan African arc assemblage comprising metavolcanics and associated volcaniclastic metasediments and arc granitoids (trondhjemite). The arc terrane is overlain in the northern part by foreland molasse type sediments. An ophiolitic melange are thrusted over the arc assemblage. The different rock types were intruded later by late collision granitoids (Fig: 1).

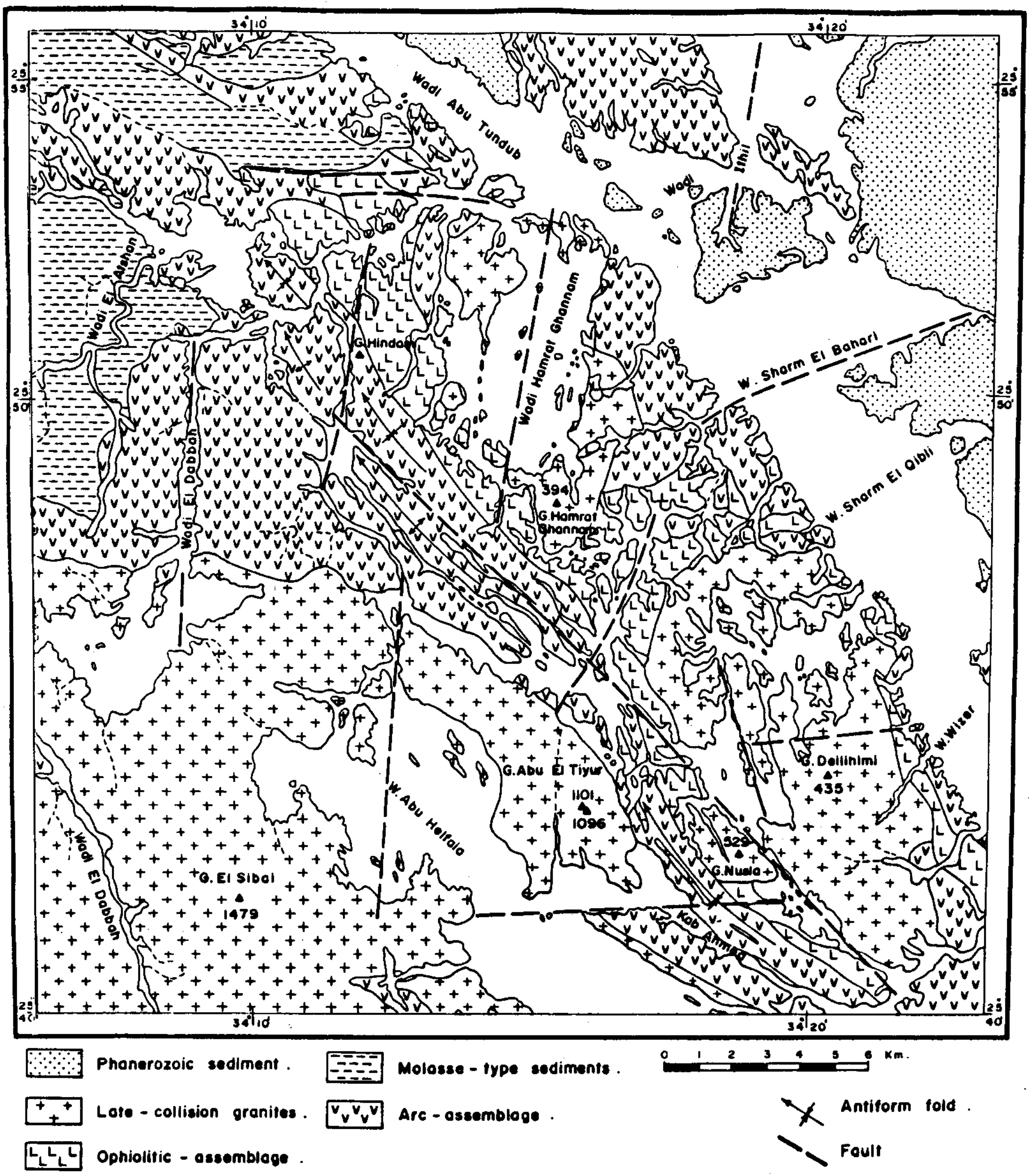

Fig. 1 : Simplified geologic map of North Abu El Tiyur area. (after Ragab et al, 1983).

The metavolcanic rocks and associated volcaniclastic metasediments form a fairly elongate belt striking northwest to the north of Gabal Abu El Tiyur and Gabal El Sibai. The rocks show different degree of deformation, depending on their proximity to the overthrusted allochthonous ophiolitic melange and the NW-SE shear zone. They grade from non-deformed to fairly mylonitic rocks close to the thrust planes. The metavolcanics comprise, meta-andesites and metadacites-rhyodacites. Most of the meta - andesites in the area are frequently porphyritic. Flow and amygdaloidal textures are present. The amygdales are usually filled with epidote, carbonates and iron oxides. Metadacites - rhyodacite rocks are microcystalline. They exhibit microporphyritic and non - porphyritic textures.

The volcaniclastic metasediments comprise, meta-agglomerate, lapilli and ash metatuffs. The threee types usually grade to each other. The lapilli metatuff is the dominant type. It consists of lithic and crystal freqments, embedded in a tuffaceous matrix and varies in composition from intermediate to acid types. It is characterized by blastomylonitic and protomylonitic texures represented mainly by lensoidal and sheeted crystal aggregates of quartz (Fig : 2).

Fig. 2 : Mylonitized crystal lithic metatuff showing stretched quartz aggregates.

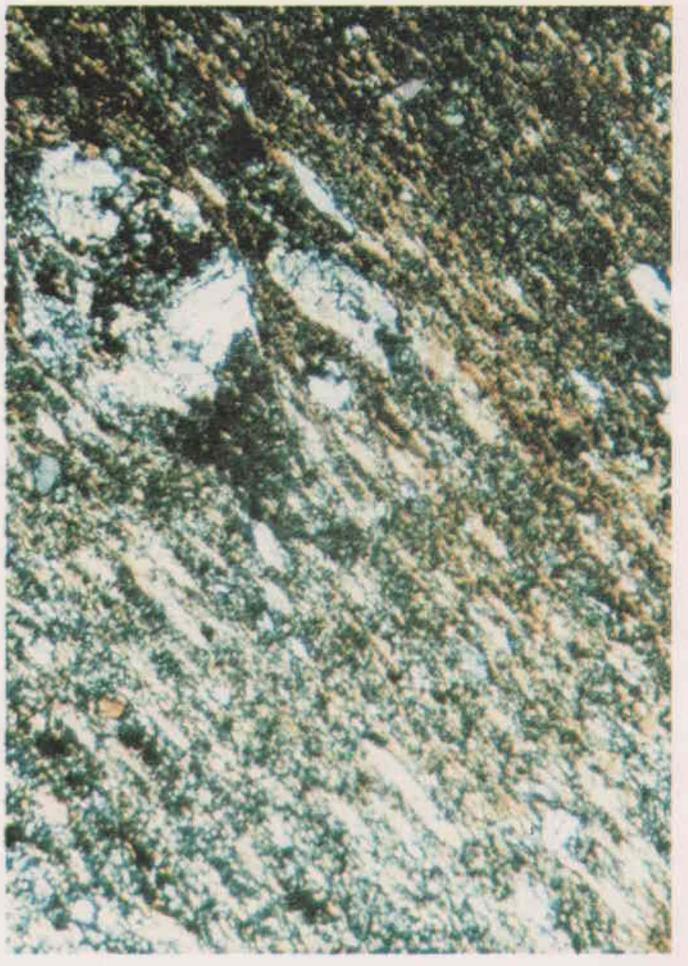

Fig. 3 : serpentized peridotite showing mesh structure in olivine crystals and altered pyroxene crystals.

The arc granitoids (trondhjemites) are characterized by greyish green color with white specks, and consist essentially of feldspar and chloritized hornblende. They are intruded by the late collision, pink alkli - feldspar granites with the development of hybrid rocks at the contact.

The molasse type sediments crop out at the northeastern corner of the area as a continuation of the well-known extensive Hammamat sediiments at Wadi Kareim. They are composed of a succession of interbeded conglomerates, red well-bedded red siltstones.

The allochthonous ophiolitic melange assemblage consistes of the following rock units :

- Dismembered ophiolites represented by large mountainous masses of talc carbonate, serpentinized peridotites (Fig : 3) metagabbros, and pillowed metabasalts. They crop out as discontinuous linear belts trending NW - SE direction. The ophiolitic melange rocks are thrusted over the metavolcanics and volcanicalstics, and are intruded by the late collision pink alkali-feldspar granites.
- Allochthonous subduction melange metasediments are composed of the trench fill low - grade metasediments compriging metagreywake, slate and phyllites. These metasediments enclose relatively small parallel mantle fragments of talc - carbonate and serpentinites.

Late collision alkali - feldspar granites are represeted by five large plutons. They have either oval or circular shape, The rocks are coarse grained, pinkish buff in color, composed mainly of alkali feldspar, plagioclase and quartz with minor biotite, and/or alkali amphibole.

GEOCHEMISTRY

The metavolcanics comprise intermediate to acid arc varieties as well as ophiolitic pillow lavas (spilites and spilitic diabase) The major and trace elements and CIPW norms of the arc varieties and pillow lava are represented

Table 1 : Major oxides, trace elements content and CIPW Norm of the studied meta-andesites and metarhyodacites.

No	1	2	3	4	5	6	7	8	9	10	11
SiO_2	27,20	58,22	59,80	62,14	63,46	66,07	66,83	67,01	69	70,43	71,83
TiO_2	0,66	0,49	16,36	0,66	0,67	0,80	0,47	0,42	0,51	0,33	0,60
Al_2O_3	16,82	17,63	16,18	15,93	14,84	14,55	14,56	16,45	14,18	11,21	14,47
Fe_2O_3	7,10	7,29	6,93	5,65	5,65	4,94	4,11	2,70	3,63	6,16	2,44
MnO	0,07	0,10	0,12	0,09	0,11	0,03	0,07	0,02	0,07	0,06	0,05
MgO	6,16	3,53	2,75	1,98	1,49	2,05	2,90	1,37	1,30	3,49	0,95
CaO	4,14	5,11	5,78	3,31	3,59	0,62	4,66	0,41	0,87	0,21	0,35
Na_2O	3,45	4,16	5,69	6,46	5,46	3,99	2,61	2,58	1,25	2,66	1,83
K_2O	1,80	0,69	0,22	0,14	1,73	1,83	1,14	4,96	4,49	1,20	3,26
P_2O_5	0,16	0,08	1,10	0,12	0,13	0,13	0,07	0,04	0,11	0,04	0,10
H_2O	0,31	0,17	0,73	0,54	0,62	0,78	0,13	1,40	1,19	1,02	1,38
CO_2	2,21	1,21	1,05	1,97	1,72	2,35	2,27	1,09	1,22	2,38	1,79
Total	100,08	99,68	99,68	98,99	99,01	98,14	99,82	98,45	98,57	98,59	99,05
Ba	404	196	92	36	430	340	206	321	555	179	453
Cr	25	44	25	63	28	30	44	33	27	82	36
Cu	55	13	59	11	17	24	44	23	29	17	30
Ga	14	21	18	19	23	21	-	16	17	30	18
Nb	39	100	4	5	13	4	4	3	8	6	10
Ni	21	15	11	18	14	13	65	< 5	11	57	9
Pb	10	8	7	9	11	5	-	7	8	10	5
Rb	21	13	< 5	< 5	37	94	23	92	98	25	77
Sc	18	23	21	19	16	16	-	17	15	4	13
Sr	465	239	175	280	203	142	199	149	31	48	49
V	175	184	176	116	59	178	135	181	79	35	105
Y	39	18	16	29	63	4	11	6	40	99	42
Zn	67	72	70	71	94	22	50	25	57	178	34
Zr	158	101	90	136	383	116	100	104	183	815	221
Qz	17,21	12,36	11,72	13,43	15,65	32,75	38,26	31,51	43,20	47,91	48,85
Or	10,50	04,19	01,33	00,86	10,52	11,38	01,34	30,54	27,58	07,45	20,09
Ab	30,65	36,17	44,11	56,61	47,55	35,52	22,64	22,74	11,00	18,30	16,14
An	05,55	25,51	21,72	14,57	11,20	02,34	08,51	01,85	03,74	00,82	01,13
Hy	17,12	16,69	11,37	08,37	05,08	07,14	12,23	03,55	03,99	15,43	02,46
Di	-	-	05,78	01,34	05,13	-	-	-	-	-	-
Ol	-	-	-	-	-	-	-	-	-	-	-
Mt	04,47	2,97	2,88	03,25	03,24	03,51	-	01,42	03,03	02,79	-
hm	-	-	-	-	-	-	-	01,02	-	-	02,19
Il	00,88	00.96	00,86	01,30	0131	01,60	00,14	00,83	01,01	00,66	00,86
Ap	00,29	00.19	00,24	00,29	00,31	00,32	00,17	00,10	00,27	00,10	00,24
C	07,73	00,97	-	-	-	05,46	06,13	06,45	06,18	06,55	07,86
cc	05,60	-	-	-	-	-	10,58	-	-	-	-
Ne	-	-	-	-	-	-	-	-	-	-	-

Table 2 : Major oxides, trace elements content and CIPW Norm of the studied ophhiolites .

No	1	2	3	4	5	6	7
SiO_2	43,61	44,08	46,25	47,70	50,04	51,1	54,41
TiO_2	0,87	1,45	2,44	0,72	1,07	1,82	0,86
Al_2O_3	16,70	14,00	16,27	17,50	13,67	17,02	22,15
Fe_2O_3	7,14	16,14	11,07	10,81	11,73	9,13	4,31
MnO	0,16	0,26	0.17	0,17	0,18	0,14	0,07
MgO	5,91	8,23	5,47	8,70	7,57	6,08	1,73
CaO	19,55	11,90	6,72	11,70	8,18	8,48	7,71
Na_2O	0,71	1,86	3,64	2,30	4,28	3,47	4,68
K_2O	0,04	0,73	1,97	0,18	0,24	0,81	4,16
P_2O_5	0,16	0,08	0,35	0,06	0,59	0,34	0,04
H_2O	1,18	0,11	0,19	0,10	0,31	0,37	0,20
CO_2	2,35	1,50	3,50	1,15	2,41	1,39	1,73
Total	98,38	100,34	98,04	101,09	99,97	110,15	101,05
Ba	15	208	228	37	48	318	176
Cr	66	113	187	273	297	213	234
Cu	12	90	37	59	61	43	13
Ga	14	-	23	20	16	24	-
Nb	6	1	18	1	1	12	3
Ni	51	50	52	260	74	100	97
Pb	5	-	21	-	7	-	-
Rb	5	19	11	12	< 5	19	23
Sc	32	-	35	39	43	-	-
Sr	54	335	250	231	466	449	422
V	231	433	266	371	326	195	77
Y	19	23	29	16	28	28	25
Zn	77	129	262	-	84	70	47
Zr	57	55	184	39	79	135	267
Qz	-	-	-	-	-	3,32	8,77
Or	0,13	3,19	12,53	1,06	1,46	4,79	1,17
Ab	0,92	16,34	33,14	19,44	37,23	29,36	40,16
An	44,84	28,74	19,69	36,87	17,47	28,47	21,01
Hy	-	3,18	0,23	16,10	1,68	16,37	10,42
Di	46,04	18,32	11,09	11,20	19,85	4,75	-
Ol	0,95	22,54	11,31	6,30	15,77	-	-
Mt	2,95	-	6,15	3,35	3,83	6,47	-
hm	-	-	-	-	-	-	-
Il	0,85	0,51	4,99	1,37	2,09	3,46	0,14
Ap	0,39	0,19	0,88	0,47	0,22	0,79	0,09
C	-	-	-	-	-	-	5,67
cc	-	7,08	-	3,50	-	-	12,59
Ne	3,17	-	-	-	-	-	-

in tables and 1 and 2. The Al_2O_3 contents of the analyzed meta - andesite metarhyodacite rocks spilites and spilitic - diabase are in the range of 14.47 to 17.63% and 13,67 to 22,5%, respectiively .

The data of the metavolcanic rocks of the area shows that the meta - andesite rhyodacite fall in the alkaline field when plotted on the alkali's silica diagram (Fig: 4) adopted by MacDonald, 1968 [2]. The spillite samples plot in the alkaline field exhibiting a wide range of variation and having an almost linear relationship. This is considered by Vallance, 1960 [3] to be characteristic of spilitic rocks.

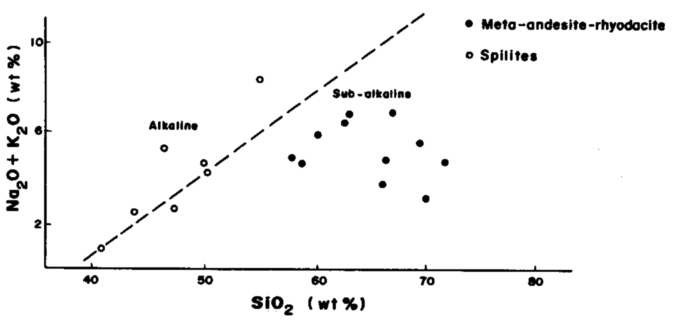

Fig. 4 : Alkali - silica diagram for the studied metavolcanics.

The AFM values for the metavolcanics in the studied areas are plotted on the AFM diagram constructed by Wager and Deer, 1939 [5] to differentiate between calc-alkaline and tholeiitic magma (Fig : 5). The meta - andesite - rhyodacite rocks are predominantly calc-alkaline, whereas the spilites and spilitic - diabase plot in the field of tholeiites.

Miyashiro [6] has shown that the relationship between the ferromagnesian elements during fractionation may persist through low grade metamorphism and may be diagnostic of tholeiitic magma. It can be also used as a quantitive parameter representing the degree of fractional crystallization, and identifying the volcanic arc complexes. Figs : 6,7,8, show the relation between FeOt/Mg versus SiO_2, TiO_2, and FeOt, resectively. The meta - andesite - rhyodacite rocks lie in the field of calc - alkaline (CA), whereas the spilites fall in the field of tholeiitic (Th) as indicated in Fig : 6,7,8 also show that most of the meta - andesite - rhyodacite rocks are similar to the trend of the younger metavolcanics of Stern, 1981 [7] in the Central Eastern Desert. The spilites are plotted in the MORB field of Miyashiro 1970 [6] and belong th the old metavolcanics of Sten, 1981 [7].

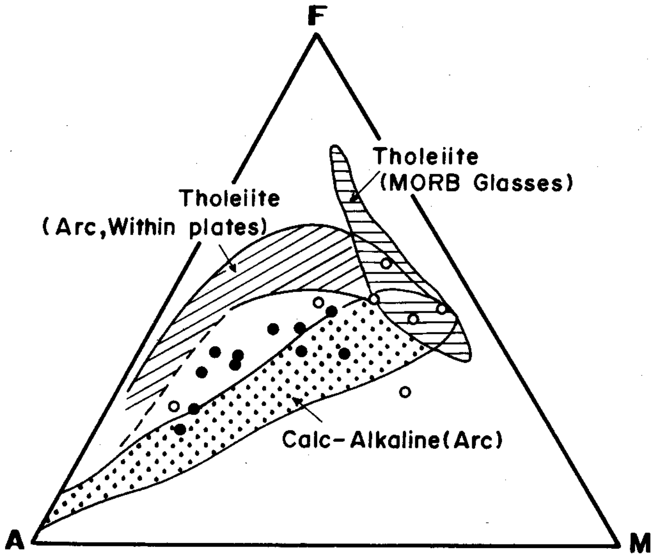

Fig. 5 : AFM diafram for the studied metavolcanics and ophiolites showing the tholeiites and calc - alkaline series (fields after Condie 1989 [4]).

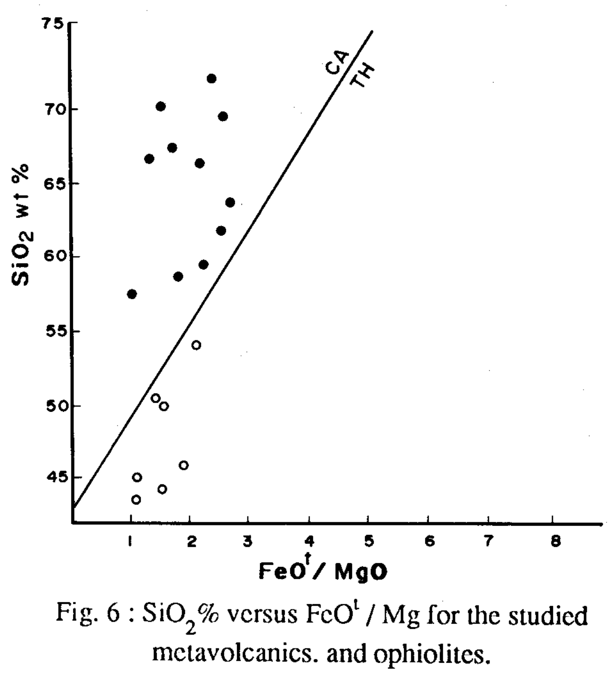

Fig. 6 : SiO_2% versus FeO^t / Mg for the studied metavolcanics. and ophiolites.

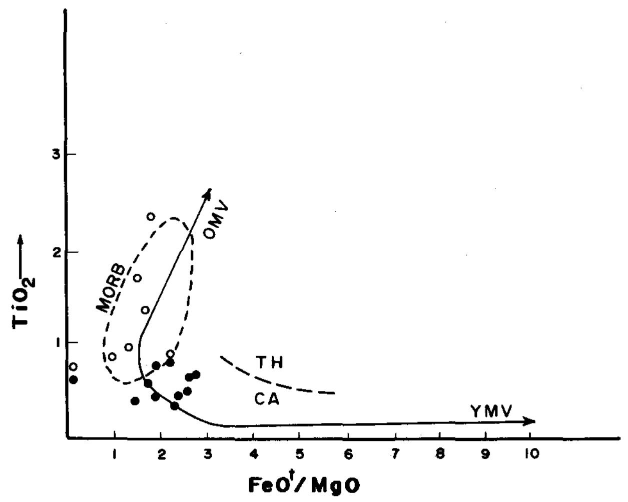

Fig. 7 : TiO_2 versus FeO^t /Mg for the studied metavolcanics. and ophiolites.

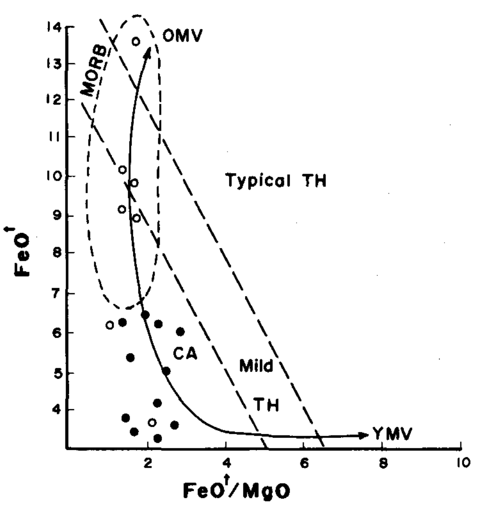

Fig. 8 : FeO^t versus FeO^t /Mg for the studied metavolcanics. and ophiolitics. Solid lines are trends of YMV and OMV of Central Eastern Desert (after Stern, 1989 [7]).

Taylor and White, 1966 [8] used the variation of log V versus log Cr (Fig: 9) in order to differentiate between the various tectonic setting and magma types. The meta - andesite - rhyodacites belong to the younger metavolcanics of Stern, 1981 [7], whereas the spilites belong to the older metavolcanics.

Table 3 shows representative chemical analyses of major and some trace elements in metagreywakes. Based on data of Paleozoic greywakes of eastern Australia, Bhatia and Crook, 1986 [9] stated that there is a systematic increase in LREE (La, Ce, Nd); Hf, Ba/Sr, Rb/Sr, La/Ya and Ni/Co and decrease in ferromagnesian elements (Sc, V, Cu Zn) and Ba/Rb, K/Th, K/U ratios from oceanic island arc to active continental margin greywakes. Variations in some of the trace elements are similar to those seen in orogenic andesites passing from immature intra - oceanic island arcs to mature island arcs to Andean type active continental margin tectonic setting (Baily, 1981) [10]. The trace elements data of the studied greywakes show decrease of Ba/Sr and Rb/Sr. The vanadium and Scandium, which are resides with the mafic components of the present metagreywakes fall in the field of oceanic island arc (Fig: 10). Accordingly, we consider the studied metasediments as volcanogenic turbidites, derived from immature intra-oceanic island arcs, which accreted tectonically with the associated oceanic plate slivers to form subduction melange at a convergent plate mariign before the obdiuction and overthrusting event.

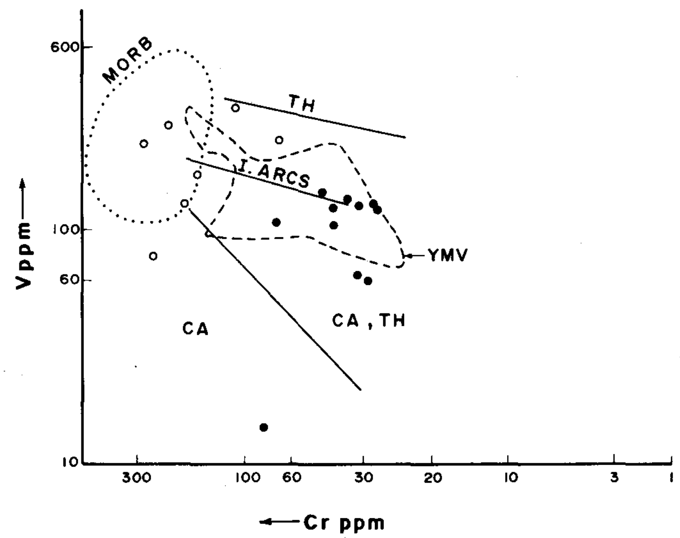

Fig. 9 : Log V versus Cr diagram for the studied ophiolites and metavolcanics. Dashed lines are the fields of YMV and OMV of Central Eastern Desert (after Stern, 1989 [7]).

Table 4 represents the results of analyses of eleven samples of granitoid rocks for the major and some minor and trace elements. The CIPW norm values of the analyzed granitoids are calculated and also given in table 3. SiO2 ranges from 58% to 77%. The granites are characterized by high SiO_2 content whereas the trondhjemites are characterized by relative low SiO_2 content (average 60,3%). The MgO%, CaO% contents are relatively low, and Na_2O is high in the alkali - feldspar granite. Meanwhile the MgO%, CaO% and Na_2O% contents are high in trondhjemite. Al_2O_3 does not exceed 14,66% in the alkali - feldspar granites, whereas it reaches up to 16,18% in the trondhjemite. K_2O% is low in trondhjemite, whereas it is high in alkalli-felfspar granites.

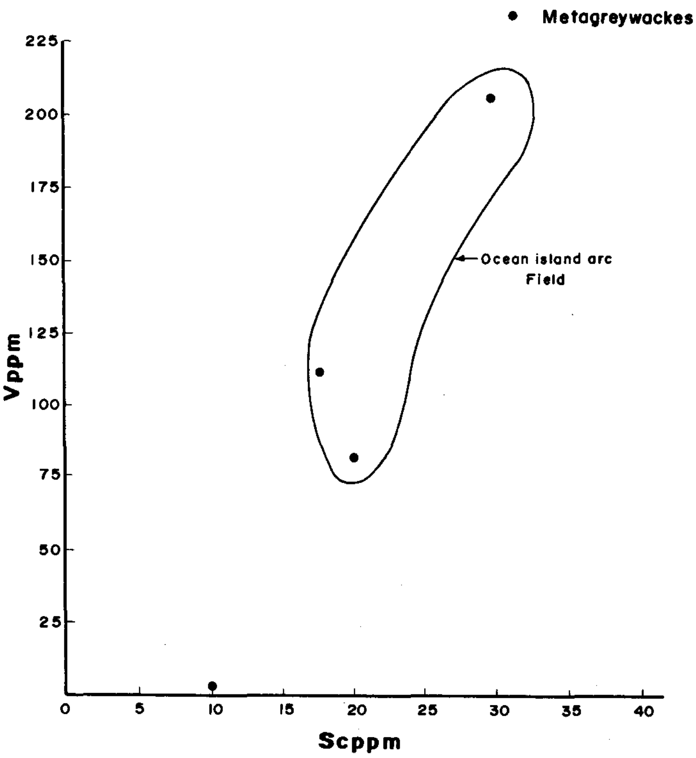

Fig. 10 : V - Sc variation diagram for the studied metagraywakes.

The magma types of the granitoid rocks are deduced from the study of the variation diagram of the three components FeO^t, $Na_2O + K_2O$, and MgO in weight percentage recalculated to 100% (Fig : 11). It is clear from the diagram that the one feldspar granites are rather poor in FeO^t and MgO, + and high in alkalies and it is evident that the trondhjemite samples show a calc - alkaline trend similar to the Cascade, Aleutian and New Zealand, meanwhile the alkkali feldspar granites lie at the apex of the differentiation trend of the calc - alkaline series.

Pearce and Gale's 1977 [11] plotted Nb versus SiO_2 for magmatiic rocks of well-known tectonic setting. They gave two different fields (within plate magmas and volcanic arc magmas). Fig : 12 shows the plot of the studies granitoids on the diagram of Gass, 1979 [12] for correlation with the Pan - African arc granitoids of the Arabian Shield and the post - Pan African within plate granitoids of northeast Sudan. The trondhjemites fall within the field of volcanic arc, whereas the alkali feldspar granites plot between the field of arc granitoids and the within plate granites suggesting collision related crustal anatexis origin.

Table 3 : Oxides and trace element contents of the metagray wakes.

No	1	2	3	4
SiO_2	55,57	63,38	63,64	85,02
TiO_2	0,40	0,52	0,35	0,08
Al_2O_3	11,34	9,89	10,20	6,26
Fe_2O_3	6,72	4,50	4,29	1,30
MnO	0,14	0,12	0,10	0,03
MgO	10,89	3,02	5,82	-
CaO	7,05	7,12	10,52	0,80
Na_2O	2,20	1,81	1,09	2,96
K_2O	1,49	1,51	0,40	0,66
P_2O_5	0,06	0,16	0,10	0,03
H_2O	0,63	0,48	0,39	0,87
CO_2	2,21	5,24	2,69	0,36
Total	98,70	97,70	99,59	98,39
Ba	526	361	125	29
Cr	206	142	34	17
Cu	9	25	11	-
Ga	12	13	14	9
Nb	-	10	3	52
Ni	93	44	34	2
Pb	5	12	6	14
Rb	30	48	14	15
Sc	29	17	20	3
Sr	77	114	208	55
V	210	113	82	11
Y	15	25	33	74
Zn	71	69	65	91
Zr	52	145	102	649

The studied granitoids were classified on the basis of their normative An- Ab- Or the diagram of Barker, 1979 [13]. The late collision alkkali feldspar granites fall in the field of granite minimum composition suggesting crusal anatexis, whereas the arc- granitoids fall in the field of trondhjemite suggesting that they represent the plutonic rocks of immature island arc (Fig : 13).

Table 4 : Major oxides, trace element contents and CIPW Norm of the studied granitoid rocks.

No	1	2	3	4	5	6	7	8	9	10	11
SiO_2	69,76	70,97	71,31	72,13	72,39	74,40	74,56	75,08	77,41	58,61	61,99
TiO_2	00,27	00,25	00,21	00,05	00,25	00,05	00,03	00,06	00,10	00,18	00,96
Al_2O_3	14,66	13,41	13,46	13,65	12,34	12,74	12,24	01,50	10,24	16,18	14,82
Fe_2O_3	02,41	02,42	01,85	02,68	02,81	02,05	01,01	01,61	01,63	8,71	5,90
MnO	00,05	00,05	00,40	00,28	00,05	00,20	00,02	00,01	00,02	1,40	0,09
MgO	00,47	00,42	00,29	00,31	00,14	00,15	00,31	00,19	00,44	1,87	1,87
CaO	01,69	01,92	01,40	00,90	01,04	00,70	00,44	00,43	00,20	4,85	3,03
Na_2O	04,95	04,09	04,40	04,42	04,73	04,73	04,65	05,12	04,17	4,84	3,03
K_2O	03,62	04,27	03,99	04,44	03,79	03,93	04,29	03,98	04,07	1,32	2,12
P_2O_5	00,02	00,07	00,06	00,08	00,06	00,06	00,01	00,02	00,01	00,35	00,17
H_2O	00,14	00,17	00,19	00,16	00,19	00,09	00,23	00,18	00,18	00,19	00,21
Total	99,74	98,90	98,40	99,88	98,73	99,26	99,69	98,96	99,38	100,06	98,76
Ba	353	546	504	293	746	153	14	14	753	367	385
Cr	15	22	15	3	15	0,8	15	14	14	3	18
Cu	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6	19
Ga	20	17	17	21	24	18	22	34	23	22	21
Nb	19	19	13	42	55	48	24	96	52	4	11
Ni	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	10
Pb	13	11	14	00	12	00	13	15	13	-	9
Rb	119	220	150	119	78	111	243	142	123	34	53
Sc	5	5	3	3	3	5	3	3	3	9	14
Sr	123	145	111	75	100	32	< 7	12	110	332	193
V	29	20	16	15	< 11	13	< 11	< 11	< 11	103	100
Y	50	44	42	57	71	74	77	161	72	47	47
Zn	48	53	43	89	104	118	30	213	105	83	72
Zr	154	238	155	261	274	311	83	280	370	234	300
Qz	23,67	27,65	28,34	28,96	29,67	40,62	31,40	32,26	39,26	13,11	15,82
Or	21,83	25,77	24,30	25,89	22,96	01,99	26,03	24,03	24,54	02,49	13,03
Ab	42,75	35,35	38,37	36,89	41,03	52,94	40,14	37,80	30,64	43,24	44,05
An	07,25	05,75	05,36	00,98	01,28	02,35	-	-	-	12,57	12,23
Hy	00,89	-	00,25	00,76	-	00,50	00,23	-	-	17,32	06,93
Di	00,66	02,75	01,06	-	00,62	00,16	00,06	00,30	00,27	-	01,85
Ol	-	-	-	-	-	-	-	-	-	-	-
Mt	01,47	01,63	-	2,35	02,60	-	-	-	-	-	03,72
Hm	00,79	00,66	01,76	00,45	-	-	01,49	-	-	-	-
Il	00,52	00,49	00,39	00,09	00,49	00,13	-	00,12	00,11	00,36	01,90
Ap	00,17	00,17	00,14	00,18	00,14	00,18	00,02	00,05	00,02	00,86	00,41
C	-	-	-	01,90	-	-	-	-	-	-	-
Cc	-	-	-	03,50	-	00,96	-	-	-	-	-

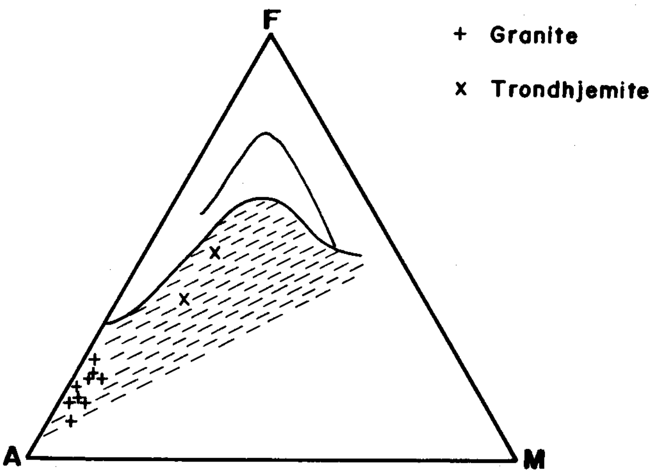

Fig. 11 : AFM diagram for the studied granitoids. The solid lines define tholeiitic trend, dashed lines defines calc alkaine trend.

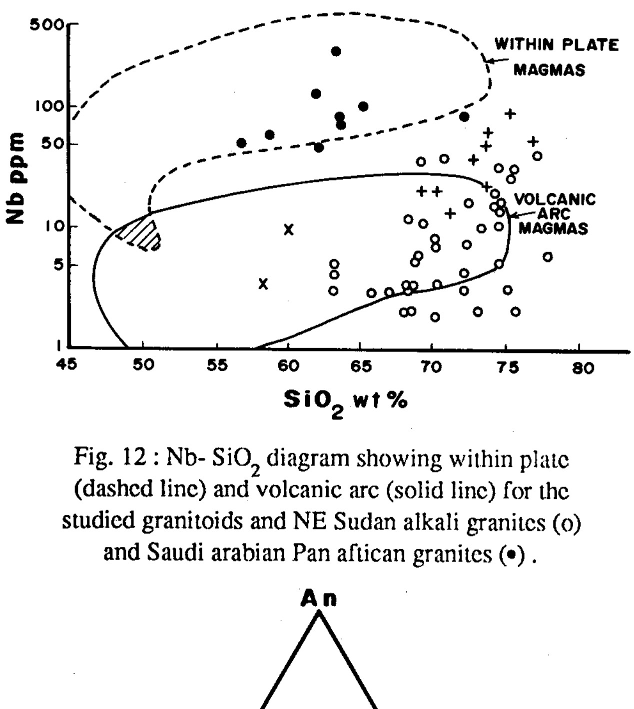

Fig. 12 : Nb- SiO_2 diagram showing within plate (dashed line) and volcanic arc (solid line) for the studied granitoids and NE Sudan alkali granites (o) and Saudi arabian Pan afican granites (•).

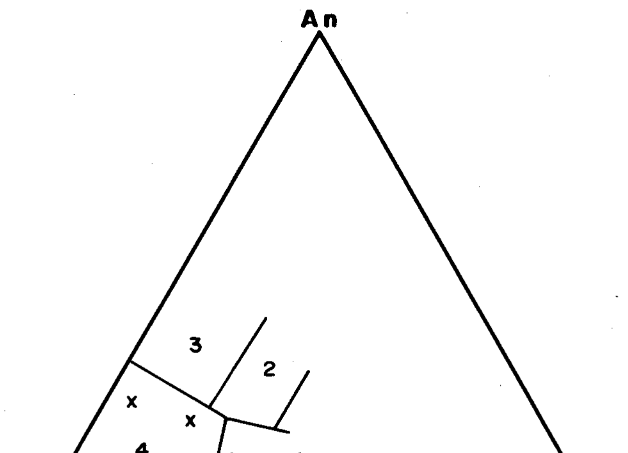

Fig. 13 : Ternary plot of normative feldspar for the studied granitoids. (1- granite. 2 - Granodiorite. 3 - Tonalite. 4 - Trondhjemite.).

CONCLUSION

Abu El Tiyur area comprises five major rock units namely: 1. volcanic rocks and associated metasediments. 2. Allochthonous ophiolitic melange 3. arc granitoids 4. late collision alkali-feldspar granite. 5. Molasse type sediments.

Two types of metavolcanics are recognized, the first type is related to the ophiolitic melange and dismembered ophiolites and exhibit tholeiitic character. The second is related however to the island arc assemblage and exhibit calc- alkaline character.

The metasediments represent volcanogenic turbidites derived from immature intra - island arcs.

The granitoids of the area are of calc- alkaline magma type, characterizing orogenic belts and belonging to the island arcs (Trondhjemite) and Collision related granites (Alakli feldspar granites).

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