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Petrology and Geochemistry of Felsic Dyke Swarms in Southwest Sinai, Egypt

Abdel - Aal M. Abdel - Karim and Ashraf F. El - Baroudy

Department of Geology, Faculty of Science, Zagazig University, Zagazig, Egypt

ABSTRACT. The southwestern part of sinai massif is formed of schist, gneiss and migmatite; a metagabbro - diorite association and granitic rocks. They are dissected by dyke swarms of several different types, ages and styles, including mafic (old) and felsic (young) suites. The felsic dyke suite is studied in terms of field, petrography and geochemistry. The majority of these dykes trend in the ENE - WSW direction. They range in composition from comendite to alkali rhyolite and true rhyolite, with 73 - 81% SiO_2 and 3.2 - 7.6% K_2O. They consist of rhyodacite, rhyolite, quartz porphyry, granite porphyry and granophyre. Porphyritic varieties contain phenocrysts of plagioclase and minor biotite and hornblende. The intrusion of these dyke swarms has occurred during the emplacement of late precambrian younger granites.

Chemically, these felsic dykes are peraluminous, enriched in K and their sialic nature suggests a derivation from upper crustal materials. Tectonomagmatic discrimination probably suggests a continental margin environment for these volcanics.

This study deals with the felsic dyke swarms of the Wadi Baba area in the southwest part of Sinai (Fig. 1) and their relationships with the late precambrian younger granites (Abdel-Karim 1992, 1993). The area is dominantly formed of precambrian basement rocks including schist, gneiss and migmatite, a metagabbro - diorite association, older granite, old (mafic) dykes, younger granite (phaseII), young (felsic) dykes and younger granite (phase III) which are partly or totally covered by paleozoic sediments. Late basalt dykes invade both the basement and sedimentary

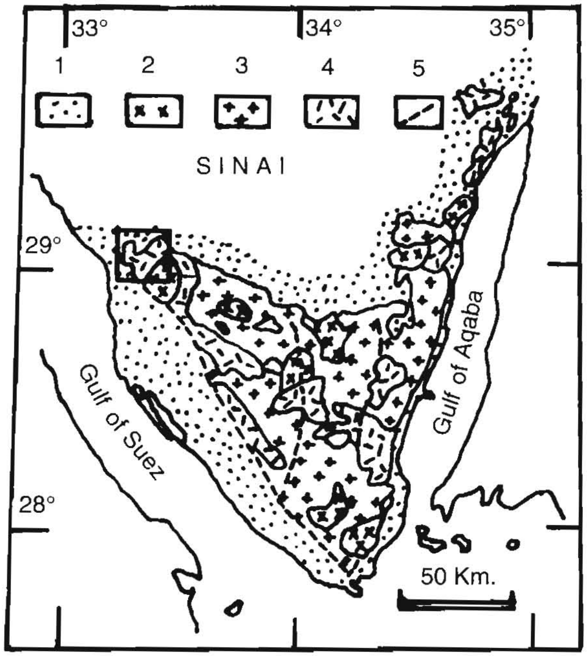

Fig. 1. Generalized geological map of the precambrian of Sinai after shimron (1980), used as location map for the studied dykes.

1: Phanerozoic sediments, 2: Young (alkaline) granitic rocks, 3: Calc alkaline granitic to dioritic rocks, 4: Other Precambrian formations, 5: Fault lines.

rocks. El-Aref *et al.* (1988) studied the basement rocks east of Abu Zenima and concluded that these dykes mark the post - tectonic extensional phase of the Pan - African orogeny. They include granite, trachyte and rhyolite dykes cutting the basement rocks. Ibrahim (1989) studied the petrology and structural setting of some dykes in the central south Sinai. She concluded that there are two set of dykes, older and younger ones. The older dykes are high–K calc-alkaline, and were generated under a tensional regime from upper mantle and lower crust materials and originated from an attenuated crust near an active continental margin with volcanic arcs. The younger ones, on the other hand, are shoshonitic in nature, of thickened crust and were generated from a continental plate margin. Hassan and Azzaz (1990) discussed the different dykes from northwest and east of the basement complex of Sinai and concluded that they are of a comagmatic affininty.

More than 30 representative younger dyke samples were collected. 8 samples were modally ananlyzed and 12 samples were chemically analyzed for major and trace elements, to complete this study.

Field Observation and Morphology

The geologic setting based on field observations, distribution, trends, morphology and cross - cutting relationships suggest two suites of dykes including mafic (old) and felsic (young) (Abdel-Karim and Azzaz, in press). The felsic dyke swarms generally vary in width from a few metres to several tens of metres and in length from a few hundred metres to several kilometres. The majority of these dykes have a tendency to form parallel swarms with a variable thickness. Generally they are either straight or curved, vertical or inclined (Fig. 2). The contact between the felsic dykes and the wall rock is generally sharp (but a distinctive chilled margin is not found in the studied dykes). Wall rock alteration in most cases is not pronounced. Most of these dykes are dissected by two perpendicular sets of joints.The dykes are pink to brown in colour, mostly porphyritic on the weathered surface and are more resistant to erosion than the country rocks particularly the metagobbro - diorite association. Two main trends for the felsic dykes are observed in the rose diagram (Fig. 3). They dominantly strike ENE - WSW with minor NNE - SSW trends. The felsic dykes invade the basement rock - units (*e.g.* schists, gneisses and migmatites, a metagabbro - diorite association and older granites together with the old dykes). Also, these dyke swarms invade the phase II granites but not the phase III of younger granites (Fig. 4). This characteristic feature probably indicates that the intrusion of the dyke suite was during or directly after phase II, but before or during the emplacement of phase III of the younger granites. The felsic dyke swarms are distributed in the southern part of the mapped area (Wadi Abu Tiur and Wadi Iqna). In the southeastern part (*e.g.* Wadi Abu Tiur) rhyodacite and rhyolite porphyry dykes have invaded the younger granites phase II (Fig. 4). These dyke swarms are probably injected in the fracture framework of the area which may have resulted from tectonic deformations of various ages and styles, which affected the sinai massif.

Petrography and Modal Analysis

The studied dykes consist of rhyodacite, rhyolite, quartz porphyry and granite porphyry and granophyre. The rhyodacite porphyry exhibits porphyritic textures. It contains phenocrysts (14.5-16%) mostly of plagioclase (An 18-25) and biotite embedded in a fine grained felsitic groundmass consisting of microlitic plagioclase, K - feldspar, quartz, hornblende and biotite with minor zircon, apatite and secondary chlorite (Fig. 5). The rhyolite porphyry is composed of phenocrysts (7-9%) of microcline perthite and quartz embedded in a fine grained vesicular groundmass of the same composition and plagioclase, biotite, chlorite and opaques. Intergrowth of feldspar and quartz in radial clusters is also common.The granite dykes are mostly porphyritic (granite porphyry) and minor equigranular (microgranite). The granite porphyry consists of phenocrysts (3.5-7%) of microcline perthite and quartz enclosed in a microcrystalline and micrographic groundmass of the same minerals together with minor amounts of plagioclase, biotite, titanite and secondary chlorite (Fig. 6). The quartz porphyry consists of quartz phenocrysts embedded in a groundmass similar to that of the granite porphyry. The granophyre consiste of phenocrysts (8-9%) of plagioclase and K - feldspar in a fine grained granophyric groudmass of plagioclase, K - feldspar, quartz, biotite and hornblende (Fig. 7).

The modal composition of selected eight felsic dyke samples are plotted on Streckeisen's diagram (1979). The felsic dyke swarms range in composition from dacite to rhyolite and alkali feldspar rhyolite (Fig. 8).

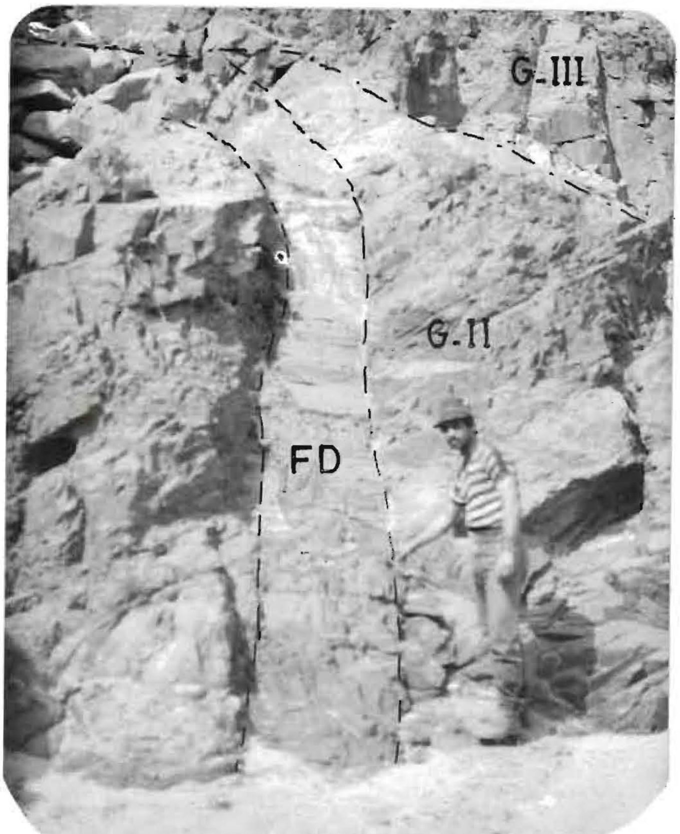

Fig. 2. Photograph shows a vertical uniform felsic dyke (FD) (rhyodacite) cross cutting the younger granites phase II (G - II). The dyke stop at the contact of younger granite phase III (G - III), Wadi Baba.

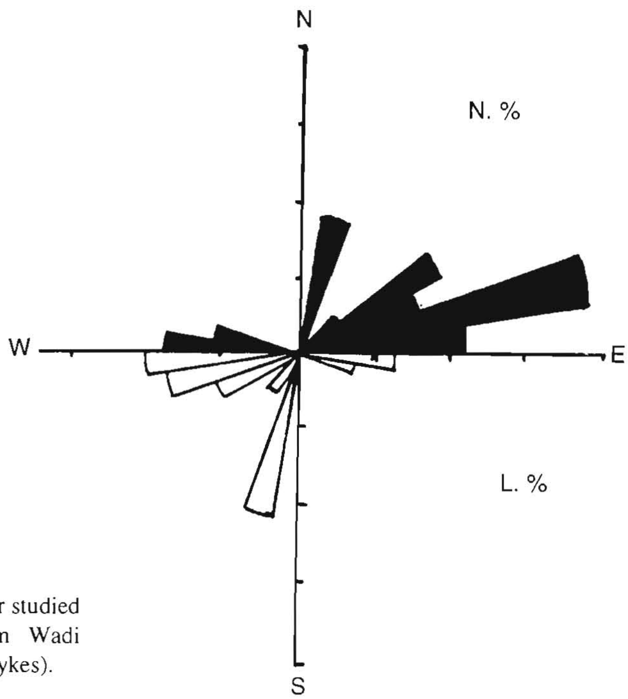

Fig. 3. Frequency rose diagram for studied felsic dyke swarms from Wadi Baba area (120 measured dykes).

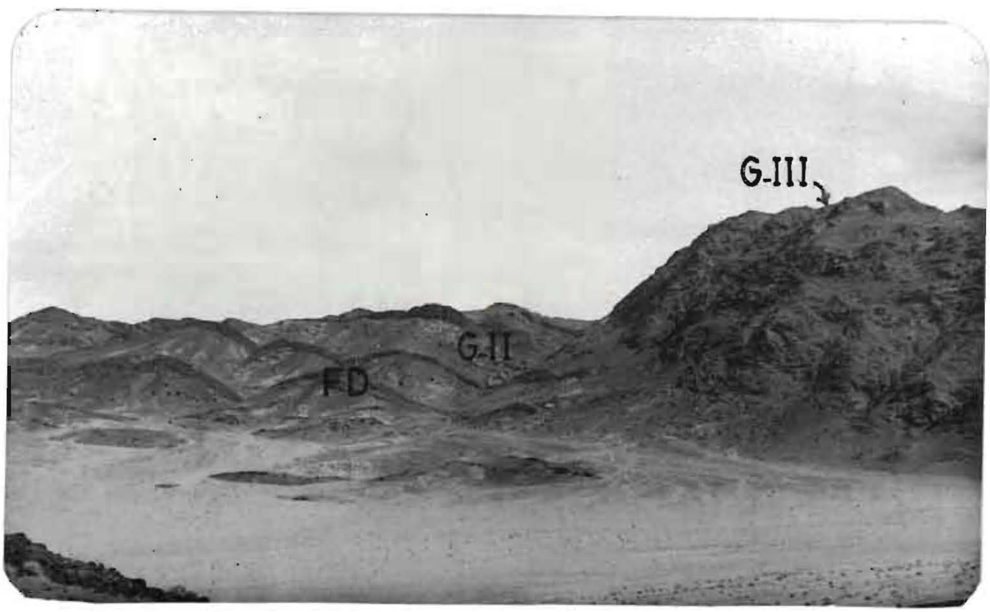

Fig. 4. Photograph shows a swarm of felsic dykes (FD, rhyolite and granite porphyry) intruding the younger granite phase II (G - II) and stopping at the contact of the phase III (G - III), south wadi el - Sahu.

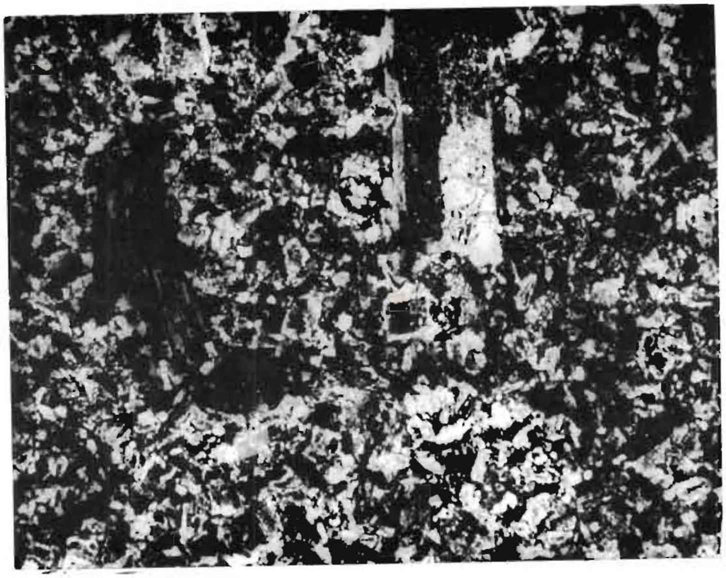

Fig. 5. Photomicrograph of rhyodacite showing phenocrysts of plagioclase and biotite embedded in a microcrystalline groundmass of quartz, plagioclase and K - feldspar. C.N., 37X

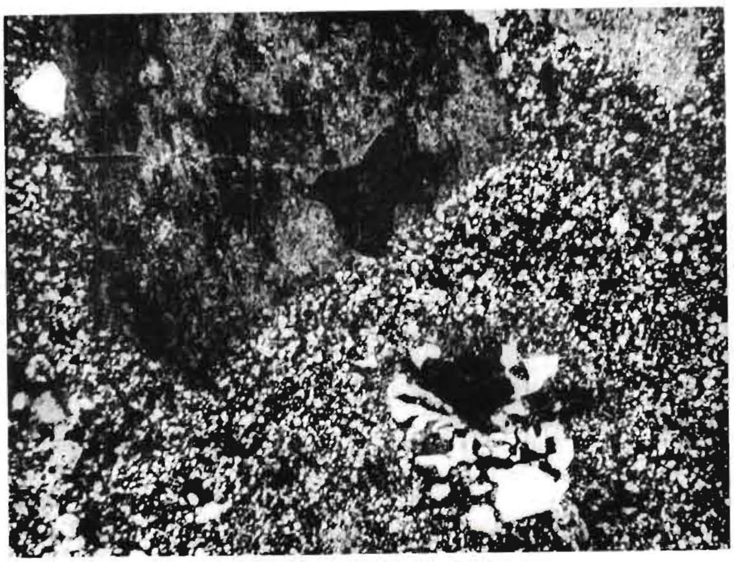

Fig. 6. Photomicrograph of granite porphyry showing a K - feldspar phenocryst enclosed in a microcrystalline and micrographic groundmass of quartz, K - feldspar and plagioclase. C. N. 37X

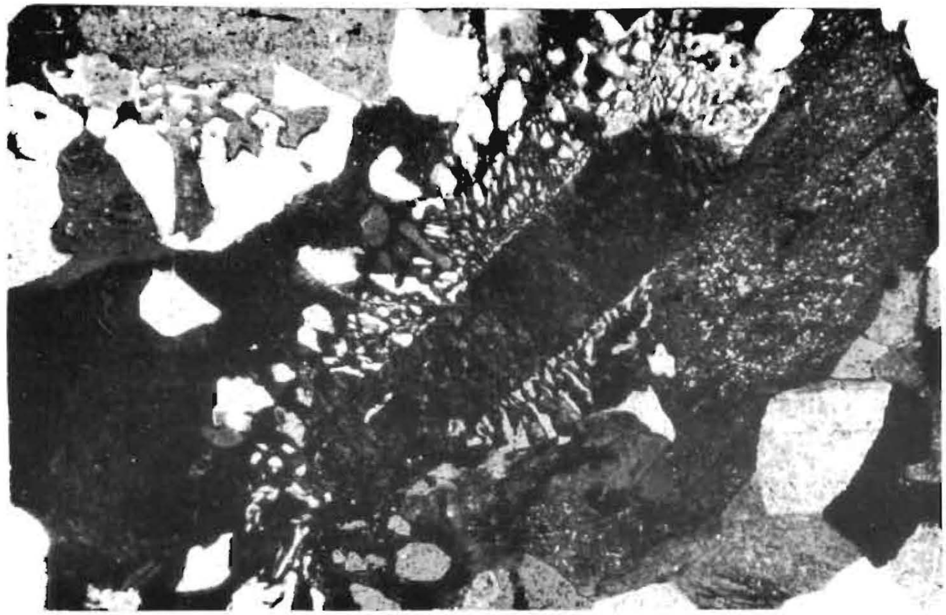

Fig. 7. Photomicrograph of granophyre showing a granophyric intergrowth of quartz, K - feldspar and plagioclase. C.N. 42X.

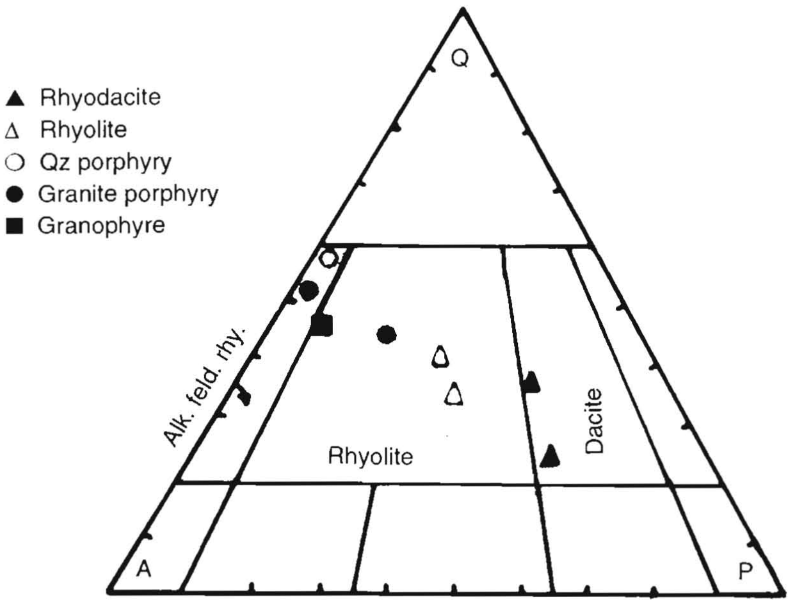

Fig. 8. Plot of the felsic dykes on the AQP classification diagram (Streckeisen 1979).

Geochemical Characteristics

Twelve samples selected from the felsic dykes were analyzed for their major and trace element contents by standard wet chemical techniques. The analyses were carried out by Dr. L. Hofmann and Nagy Belane in the Departement of Petrology and Geochemistry of Eotvos University, Hungary. The results appear in Table 1. The average chemical composition of the analyses given by Ibrahim (1989) for the dyke swarms in central south sinsai are also presented (Table 2), for reference. The data have been utilized to predict the classification, magma type and tectonomagmatic setting of the investigated dyke swarms.

Chemical Classification

The felsic dykes of the SW Sinai are chemically discriminated into different magma series and their differentiation products in terms of Zr/TiO_2 and Nb/Y ratios, after Winchester and Floyd (1977). On this diagram (Fig. 9), most analyses fall

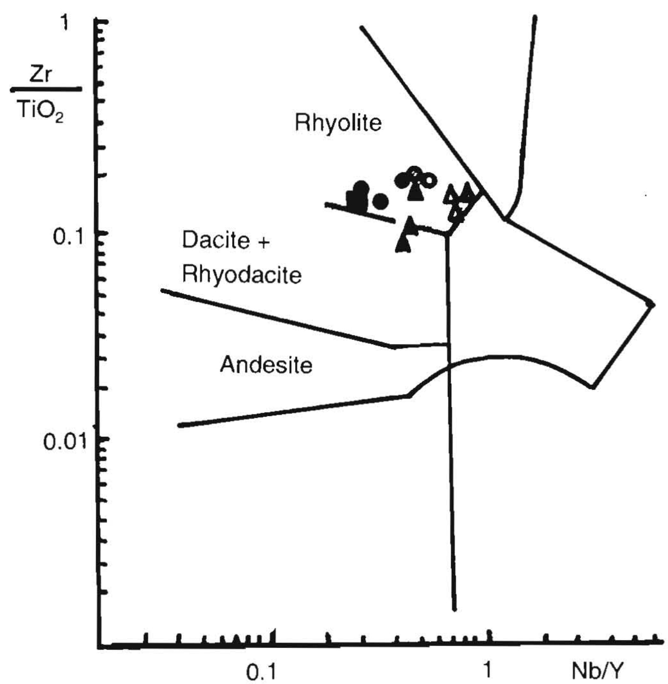

Fig. 9. Plot of felsic dykes on Zr/TiO_2 - Nb/Y classification diagram (Winchester and Floyd, 1977).

Table 1. Major and trace element compositions of the felsic dyke swarms, southwest Sinai

	Comendite Rhyodacite porph.			Alkali rhyolite Grphy. Granite porph.				Rhyolite Qz porph.		Rhyolite porph.		
	275	190	101	125	291	12	47	242	250	293	166	7
SiO_2	72.91	73.57	74.44	73.01	76.78	77.05	77.63	78.54	80.03	77.86	79.83	81.16
TiO_2	0.19	<0.10	<0.10	<0.10	<0.10	<0.10	<0.01	<0.10	<0.10	<0.10	<0.10	<0.10
Al_2O_3	11.54	12.06	11.25	14.03	10.50	10.63	11.43	10.40	10.05	10.03	9.05	8.50
Fe_2O_3	<0.10	1.27	0.59	0.76	1.18	0.90	0.46	1.10	1.11	0.91	1.29	1.28
FeO	2.22	1.37	0.95	0.85	0.19	0.34	0.67	0.19	0.17	0.18	0.35	0.10
MnO	0.01	0.04	<0.01	0.02	<0.01	<0.01	0.05	<0.01	0.03	0.04	<0.01	<0.01
CaO	0.67	0.70	0.70	0.87	0.25	0.45	0.60	0.12	0.11	0.50	0.19	0.25
MgO	0.47	0.36	0.70	0.20	<0.10	<0.10	<0.10	0.30	0.20	<0.10	<0.10	<0.10
Na_2O	4.60	4.47	3.81	5.32	4.06	4.03	4.56	0.21	0.14	4.20	3.71	4.54
K_2O	5.20	4.68	6.03	3.69	5.02	4.75	4.35	7.61	6.50	3.25	4.23	3.36
$+H_2O$	1.25	0.99	1.11	0.75	0.56	0.72	0.02	1.03	1.20	1.46	0.58	0.45
$-H_2O$	0.22	0.23	0.16	0.18	0.13	0.16	0.10	0.28	0.19	0.24	0.18	0.10
P_2O_5	0.03	0.04	0.05	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sum	99.41	99.88	99.90	99.80	98.89	99.25	99.99	99.90	99.84	98.88	99.73	99.96
Ba	714	550	630	1110	450	270	250	272	350	290	210	285
Rb	125.6	99.5	112	73.8	82	98	97.5	93.5	92	97	109	101
SR	510	395	318	302	255	205	120.8	108	190	172	95	107
Nb	15	12.5	11.7	14	13.3	11.6	11	12.2	13	12.5	12	13.5
Y	25	19	18	45	34	23	32	24	22	15	12	17
Zr	189	194	182	163	157	173	165	159	175	165	163	140
Sc	2.9	2	2.4	2.8	2.2	2.1	3.4	2.9	3	2.4	2.7	2.8
Cr	111	90	118	140	153	165	170	162	105	120	117	129

1	2	3	4	5	6	7
73.64	79.62	71.05	77.15	72.99	73.01	75.19
0.13	0.10	0.28	0.10	0.29	0.10	0.10
11.62	9.19	12.56	10.85	12.53	14.03	12.66
0.65	1.16	2.99	0.85	1.39	0.76	1.60
1.51	0.21	0.78	0.40	0.40	0.85	0.18
0.02	0.02	0.05	0.02	0.07	0.02	0.03
0.69	0.31	1.29	0.43	1.27	0.87	0.87
0.51	0.10	0.55	0.10	0.66	0.20	0.30
4.30	4.15	3.38	4.22	3.33	5.32	2.70
5.30	3.61	4.78	4.71	4.87	3.69	5.11
1.12	0.83	–	0.43	–	0.75	–
0.21	0.17	–	0.13	–	0.18	–
0.04	0.01	–	0.01	–	0.02	–
99.73	99.48	97.71	99.49	97.80	99.80	98.75
632	262	825	327	575	262	200
112	102	139	92	87	102	187
408	126	137	124	439	125	38
13	12.7	–	12	–	12.7	–
21	14.7	19	30	12	14.7	8.5
188	156	205	165	182	156	210
2.4	2.6	–	2.6	–	2.6	–
103	122	–	163	–	122	–

1 = rhyodacites, average of 3 samples, 2 = rhyolite, average of 3 samples,
3 = rhyolite, average of 4 samples (Ibrahim 1989), 4 = granite porphyry, average of 3 samples,
5 = granite porphyry, average of 4 samples (Ibrahim 1989), 6 = granophyre,
7 = granophyre, average of 2 samples (Ibrahim 1989). – = not analyzed.

within the rhyolite field and two samples fall in the dacite or rhyodacite field. The diagram also reveals that the dykesare of subalkaline nature. When these dykes are plotted in the silica - alkalis diagram (Fig. 10) of kremenetskiy *et al.* (1980), after Middlemost (1985), the rhyodacite porphyry plots in the comendite, the granophyre and granite porphyry in the alkali rhyolite and the quartz and rhyolite porphyries in the true rhyolite fields. These nomenclatures of the samples coincide with the petrograɒhic diagnosis of the rocks.

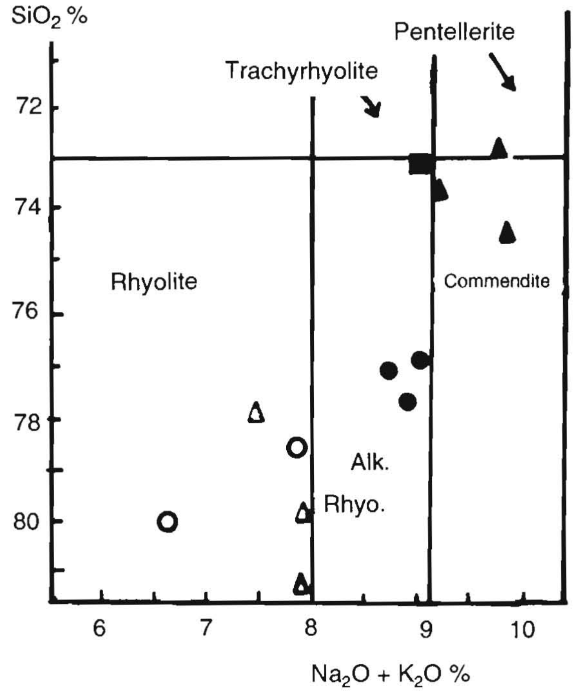

Fig. 10. Plot of the felsic dyke swarms on the silica - total alkali classification diagram (Kremenetiskiy *et al.* 1980) after Middlemost (1985).

Magma Type

The felsic dyke swarms are plotted on the alkali - silica variation diagram (Fig. 11) as defined by Irvine and Baragar (1971). They plot in the subalkaline field, and are of peraluminous nature (*i.e.* Al203 > $Na_2O + K_2O + CaO$, Table 1). On the K_2O - Na_2O diagram (Fig. 12) after Middlemost (1980), it is clear that most analyses plot in the potassic series field except the quartz porphyry samples which fall in the high-K series field. Moreover, the plotting of these dykes on the log ~ – log diagram (Fig. 13) suggests their sialic origin (Gottini 1968). The K ~– enrichement as well as the sialic nature of these volcanics probably indicate their generation from upper crustal materials within an extensional regime at a continental margin.

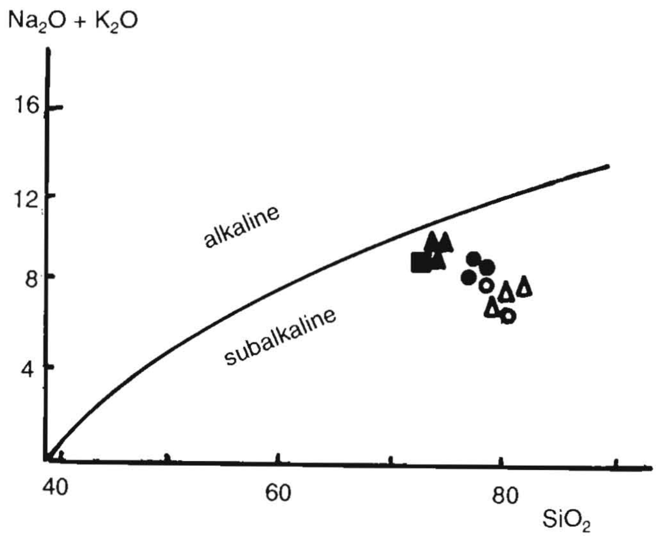

Fig. 11. Plot of felsic dykes on the total alkali - silica variation diagram (Irvine and Baragar 1971).

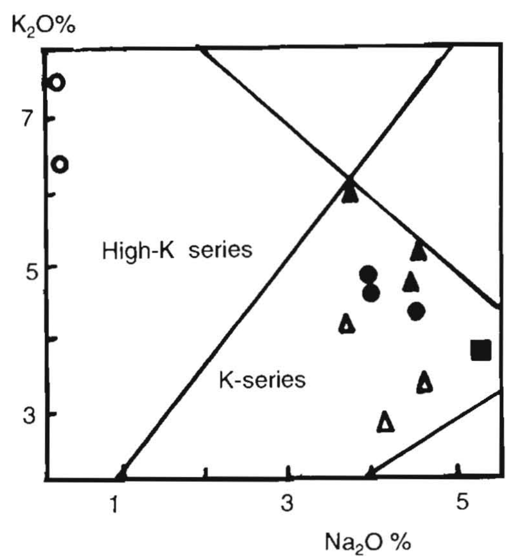

Fig. 12. Plot of the felsic dykes on the potash - soda diagram (Middlemost 1980).

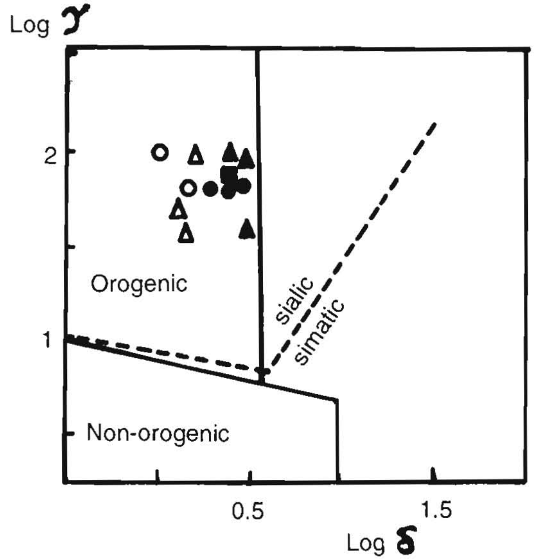

Fig. 13. Plot of the felsic dykes on the log ~ – log diagram (Rittmann 1973). Dashed line represents the sialic/ simatic boundary (Gottini 1968).

Tectonic Setting

Using the above mentioned discriminant diagram (Fig. 13), after Rittmann (1973), the examined samples plot in the field of orogenic belt and island arc volcanics indicating their origin from crustal materials. On the K_2O - SiO_2 diagram (Fig. 14), after Coleman and Peterman (1975) the dykes plot close to continental granophyre field, emphasizing their continental environment. These dykes also plot in the plate margin field of Pearce and Gale (1977) of the Zr/Y - Ti/Y diagram, (Fig. 15), where they are again clustered in the active continental margin field. A similar feature appears on the Zr - SiO_2 diagram (Fig. 16) of Ramsay *et al.* (1981).

The mineralogical and chemical characters of the dyke swarms can be compared with the active continental margin volcanics (Table 2), and show great similarities.

Table 2. Comparison of the typical active continental margin volcanics (Greenwood *et al.* 1980, Baker 1982) with the studied dyke swarms

	Active continental margin	The studied dyke swarms
Mafic phenocryst	dominantly hornblende.	dominantly biotite, minor hornblende.
Dacite and rhyolite	dominantly	dominantly
SiO_2	61-75%	73-81%, average: 77%
$Na_2O + K_2O$	5% (common)	6.6-9.8%, average: 8.5
Na_2O/K_2O	1.3 (common)	0.6-1.5%, average: 1
FeOt/MgO	high	2-15%, average: 7

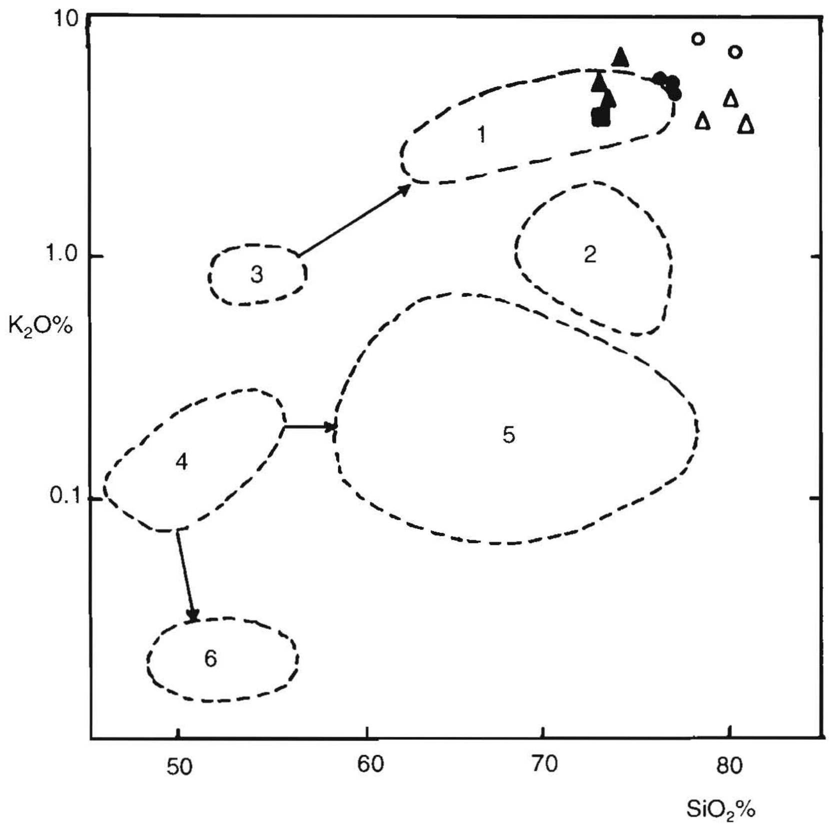

Fig. 14. Plot of the felsic dykes on the K_2O - SiO_2 diagram of Coleman and Peterman (1975). Fields: 1 = Continental granophyre and granite, 2 = Continental trondjhemite, 3 = Continental tholeiite, 4 = Subalkaline oceanic basalt, 5 = Oceanic plagiogranite and trondjhmite, 6 = Cumulate gabbro.

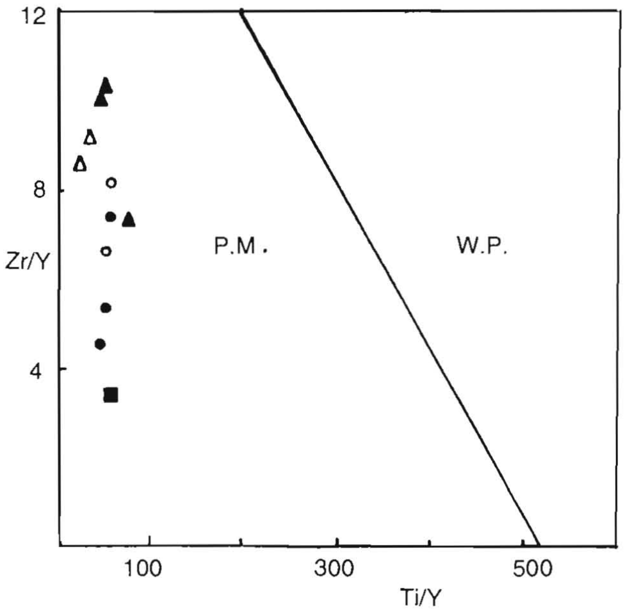

Fig. 15. Plot of the felsic dykes on the Zr/Y - Ti/Y diagram of preace and Gale (1977). P. M. = Plate margin, W.P. = Within plate.

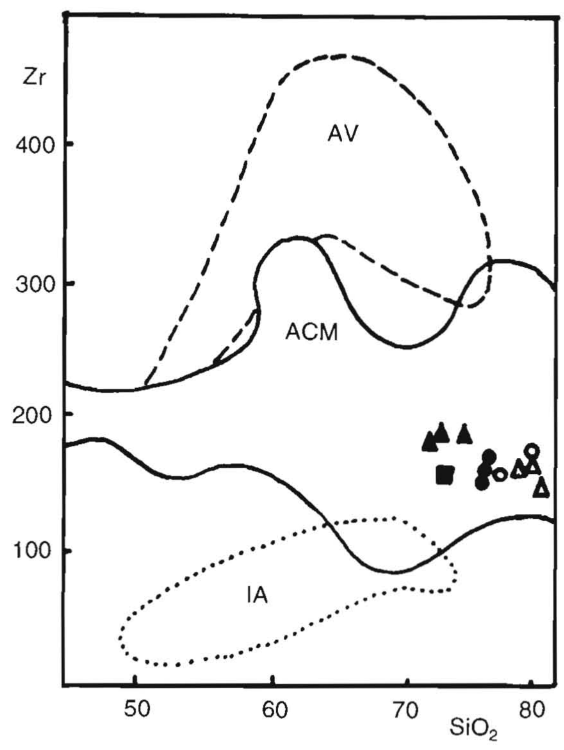

Fig. 16. Plot of the felsic dykes on the Zr - SiO_2 diagram (Ramsay *et al.* 1981, after Ewart 1979). IA = immature island arcs, ACM = active continental margins, AV = anorogenic volcanic terrains.

Summary and Conclusion

The basement rockes in the southwest Sinai are cut cross by a swarm of felsic dykes mostly trending in the ENE - WSW direction. They consist of rhyodacite, rhyolite, quartz porphyry, granite porphyry and granophyre. Their composition range from comendite to alkali rhyolite and true rhyolite.

The emplacement of the felsic dykes was contemporaneous with the emplacement of the late Precambrian younger granites. In particular, these dykes can be put between phase II and phase III of the younger granites.

Geochemically, the dyke swarms are members of the potassic series, peraluminous and sialic in origin. Therefore, they are derived from upper crustal materials.

Tectonomagmatic discrimination indicates that these volcanics have similarities to magma types of a continental margin environment.

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بترولوجية وجيوكيميائية حشود القواطع الفلسية بجنوب غرب سيناء- مصر

عبد العال محمد عبد الكريم و أشرف فوزي البارودي

قسم الجيولوجيا - كلية العلوم - جامعة الزقازيق

الزقازيق - مصر

تصنف القواطع بجنوب غرب سيناء إلى حشود قواطع مافية (الأقدم) وأخرى فلسية (الأحدث) . يعالج البحث العلاقات الحقلية ، البتروجرافية والجيوكيميائية للقواطع الفلسية والتي تتراوح في التركيب ما بين الكومنداتيت إلى الريوليت القلوي والريوليت الحقيقي والتي تمتد نسبة السيليكا فيها من ٧٣- ٨١٪ وأكسيد البوتاسيوم من ٢ ,٣-٦ ,٧٪ . وتقابل هذه الحشود الريوداسايت ، الريوليت ، الكوارتز بورفيري ، الجرانيت البورفيري والجرانوفير . والأنواع البورفيرية منها تحتوي على بلورات كبيرة من البلاجيوكليز مع القليل من البيوتايت والهورنبلند . وتتزامن هذه القواطيع في تداخلها مع تداخل الجرانيت الحديث ما قبل الكمبري اللاحق .

ومن الناحية الكيميائية تعتبر هذه القواطع ذات طبيعة فوق ألمونية ، غنية في البوتاسيوم ومن أصل سيالي والذي يدل على أشتقاقها من المواد المكونة للجزء العلوي من القشرة الأرضية في بيئة تكتونية على حافة قارية .