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GEOLOGY, MINERALOGY AND GEOCHEMISTRY OF THE DYKES TRAVERSING WADI HAFIYA AREA, EASTERN DESERT, EGYPT

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ABSTRACT

Wadi Hafiya area is dissected by enormous number of dykes and veins of different composition. In the present work only one hundred major dykes were investigated in detail recording their strike, length, width and dip. Also studying their petrography, opaque mineralogy as well as their geochemistry. The studied dykes are categorized under three groups namely: mafic, intermediate and felsic.

The mafic dykes are represented by basalts and dolerites. They are of three main trends N35°W, N5°E and N85°W E. Their average length is 3.5 km. They generally form negative topography regarding the surrounding host rocks. Petrographically, they show ophitic, sub-ophitic and rare porphyritic texture. Their opaques (about 9% of the rock) are represented by ilmenite, magnetite and pyrite. They were originated from low- to medium-k tholeiitic magma.

The intermediate dykes are represented by andesite and rarely trachy-andesite. They are of two main trends N35°W and N85°E. Their average length is 4.3 km. They show the same topography as the host rocks. Petrographically, they show porphyritic and pilotaxitic textures. Their opaques (about 7% of the rock) are represented by magnetite, ilmenite and pyrrhotite. They were originated from medium- to high- K subalkalic magma.

The felsic dykes are represented by rhyolite, aplite and quartz-feldspar porphyry. They are of three main trends N45°E, N85°E and N45°W. They form prominent ridges with average length 3.6 km. Their opaques (3%) are mainly represented by ilmenite, magnetite and pyrite. They were originated from high- K subalkalic magma.

From the different characteristics and the cross-cut relationships it is concluded that, these dykes were formed at different periods represented by intrusion of old mafic dykes then the intermediate ones and then the felsic ones and finally other mafic ones.

1- INTRODUCTION AND GEOLOGIC OUTLINE

Wadi Hafiya area (~648 km^2) is located between latitudes 24° 51' and 25° 02' N and longitudes 33° 59' and 34° 17' E (Fig. 1a). The Precambrian rocks exposed in the area are represented by ophiolitic mélange (oldest), island arc metavolcanics, older granitoids, younger gabbros and younger granites. The ophiolitic mélange is represented by chaotic blocks and fragments of serpentinites (massive, sheared, and talc-carbonates), metagabbros, amphibolites and a matrix of metasediments (metamudstones, metagreywackes and metaconglomerates). The block/ matrix ratio is uneven allover the area. The metavolcanics cover the extreme southwestern corner of the area and they are mainly represented by metapyroclastics, little metabasalts and meta-andesites. The older granitoids cover a large part of the area and are mainly represented by quartz-diorites and granodiorites. The younger gabbros occur as three small elliptical intrusions cutting the ophiolitic mélange and the older granitoids. The younger granites (youngest) are found as masses of moderate topography scattered allover the area. They intrude all the older rocks, send offshoots into them, and carry several xenoliths and roof pendant from them. They are characterized by their cavernous weathering. A large mountain (Gabal El-Muwelha) in the southwestern corner of the area represents the highest topographic peak in it.

Wadi Hafiya area was included in several previous studies such as Hume (1907), Ball (1912), Amin et al. (1953), Mansour and Bassyuni (1954), El-Ramly and El-Far (1955), Soliman (1981) and El-Mansi (1996). These various studies do not include the dyke rocks traversing it.

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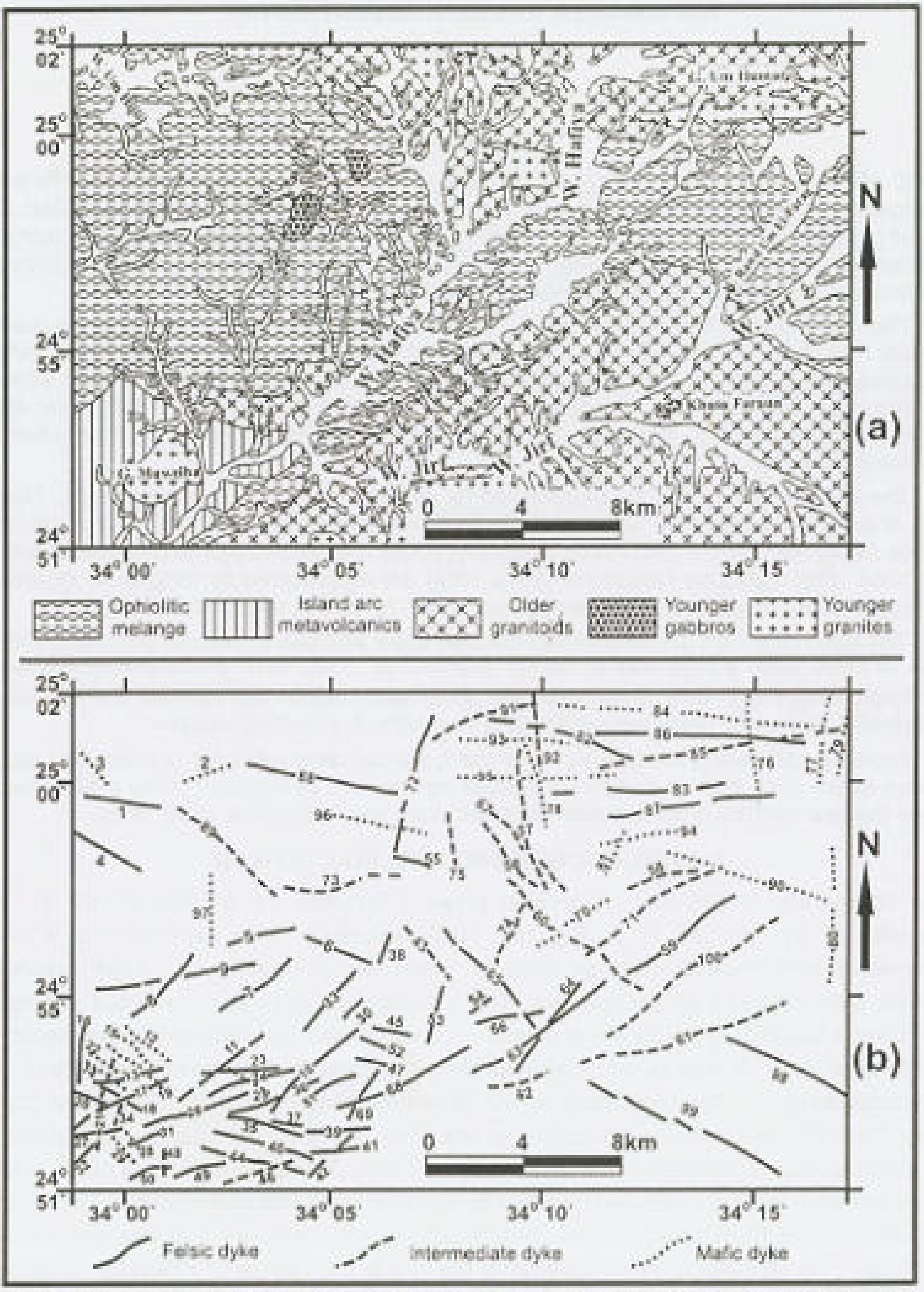

Fig.1: Geologic map of Wadi Hafiya area, Eastern Desert, Egypt (a) and distribution map of dykes traversing it (b)

2- DISTRIBUTION AND CHARACTERISTICS OF DYKES

Wadi Hafiya area is dissected by several dykes and veins of different types, trends, lengths and thicknesses. One hundred of major dykes are traced and mapped (Fig.1 b). The characteristics of these dykes (type, strike, amount and direction of dip, length and thickness) are presented in table (1). Most of these dykes show some variations in thickness and dip (amount and direction) along their courses thus the tabulated data represent the average of the measurements that were taken in several points along their courses. The directional trend analysis (Fig. 2) indicates that these dykes are of four main trends namely N85°E, N40°W, N45°E and N5°E regarding their length and number proportions.

The mapped dykes are of three main types namely mafic (24 dykes), intermediate (22 dykes) and felsic (54 dykes). They show sharp, fairly straight contacts and chilled margins. In places, well developed slickensides are observed along the dyke sides suggesting that these dykes are invaded along active shear planes.

Table (1): The characteristics of the dykes of Wadi Hafiya area

Dyke No.	Strike	Dip	Length (km)	Width (m)	Rock type
1	N70°W	65°to N	3.4	1.9	Quartz-feldspar porphyry
2	N75°E	75°toNE	2.3	2.8	Dolerite
3	N40°W	70°to E	1.4	2	Dolerite
4	N40°W	70°to N	3.2	3.1	Aplite
5	N60°E	85°to N	2.9	1.9	Aplite
6	N30°W	60°to NE	3	3.2	Aplite
7	N40°E	85°to SE	3.3	3.3	Aplite
8	N30°E	70°to SE	3.6	2.7	Aplite
9	N90°E	70°to N	6.8	3.3	Quartz-feldspar porphyry
10	N45°E	60°to SE	5	2.9	Aplite
11	N45°E	80°to NW	4.5	2.8	Quartz-feldspar porphyry
12	N30°W	75°to NE	2.7	1.7	Dolerite
13	N70°E	75°to N	3.1	1.4	Rhyolite
14	N25°W	65°to SW	2	5.6	Dolerite
15	N25°W	60°to SW	2	3.1	Dolerite
16	N5°E	80°to W	2.3	3.5	Quartz-feldspar porphyry
17	N40°E	90°	4.5	1.7	Quartz-feldspar porphyry
18	N25°W	80°to SW	2.1	1.8	Quartz-feldspar porphyry
19	N30°W	60°to SW	2.7	2.9	Dolerite
20	N38°W	50°to SW	1.8	1.9	Quartz-feldspar porphyry
21	N10°E	82°to W	4.1	2.1	Andesite
22	N30°W	90°	1.8	2.5	Basalt
23	N85°E	75°to SE	3.9	2.4	Quartz-feldspar porphyry
24	N70°E	80°to S	3.6	2.5	Quartz-feldspar porphyry
25	N40°W	74°to NE	2.1	1.5	Dolerite
26	N50°E	85°to N	4.5	1.7	Rhyolite
27	N85°E	80°to S	2.3	4.3	Quartz-feldspar porphyry
28	N32°W	57°to SW	1.6	1.1	Dolerite
29	N30°W	80°to SW	1.5	1.6	Dolerite
30	N45°E	50°to S	1.1	2.8	Quartz-feldspar porphyry
31	N55°E	73°to SE	1.6	1	Quartz-feldspar porphyry
32	N40°E	50°to S	1.2	1.8	Aplite
33	N40°W	75°to SE	3.1	2.7	Quartz-feldspar porphyry
34	N15°E	72°to E	1	1.6	Andesite
35	N70°W	60°to S	3.2	1.4	Aplite
36	N86°E	60°to SE	4.1	1.8	Quartz-feldspar porphyry
37	N55°W	65°to SE	1.4	1.5	Quartz-feldspar porphyry
38	N20°E	64°to SE	1.4	1.9	Quartz-feldspar porphyry
39	N85°E	62°to N	2.7	2.7	Rhyolite
40	N70°W	60°to S	3.7	2.8	Aplite
41	N80°E	60°to S	1.6	1.9	Aplite
42	N45°E	63°to NW	2.3	2.5	Quartz-feldspar porphyry
43	N78°W	65°to S	3.1	1.1	Andesite
44	N50°W	75°to S	4.5	1.9	Quartz-feldspar porphyry
45	N52°W	65°to S	1.8	2.5	Quartz-feldspar porphyry
46	N85°E	55°to S	3.1	1.5	Andesite
47	N40°W	63°to S	1.1	2.5	Quartz-feldspar porphyry
48	N10°E	70°to E	1.1	2	Andesite
49	N60°E	74°to NW	2.3	3.1	Quartz-feldspar porphyry
50	N85°E	65°to S	1.8	1.5	Aplite

Table (1): Continued.

Dyke No.	Strike	Dip	Length (km)	Width (m)	Rock type
51	N48°E	68°to NW	2	2.5	Quartz-feldspar porphyry
52	N42°W	63°to SW	1.1	3.6	Quartz-feldspar porphyry
53	N20°E	80°to E	2.3	2.4	Rhyolite
54	N38°E	70°to NW	1	3.5	Andesite
55	N60°W	75°to E	1.1	3.1	Rhyolite
56	N30°W	90°	3.8	2.2	Andesite
57	N5°E	85°to E	6.2	3.1	Andesite
58	N65°E	90°	2.8	2.6	Andesite
59	N40°E	90°	5.8	2.1	Quartz-feldspar porphyry
60	N36°W	83°to E	7.3	1.4	Andesite
61	N60°E	88°to N	7.3	3.1	Andesite
62	N80°E	90°	2.5	3.6	Andesite
63	N40°E	90°	6.4	2.2	Quartz-feldspar porphyry
64	N40°E	90°	4.6	2.5	Quartz-feldspar porphyry
65	N20°W	90°	5.9	1.2	Quartz-feldspar porphyry
66	N70°E	80°to S	2.7	1.5	Quartz-feldspar porphyry
67	N30°W	80°to NE	4.5	3.2	Andesite
68	N60°E	87°to N	6.1	3.2	Quartz-feldspar porphyry
69	N30°E	77°to W	2.7	3.4	Quartz-feldspar porphyry
70	N52°E	85°to N	3.6	2.4	Dolerite
71	N50°E	90°	6.8	2.1	Andesite
72	N20°E	74°to E	6.4	1.3	Quartz-feldspar porphyry
73	N70°W	72°to N	4.6	1.1	Andesite
74	N35°E	90°	2.8	3	Andesite
75	N5°E	90°	2.3	3.5	Andesite
76	N5°E	90°	4.5	1.2	Basalt
77	N10°E	90°	3.6	2.5	Dolerite
78	N7°E	85°to W	3.7	1.4	Basalt
79	N10°E	90°	3.4	2.1	Dolerite
80	N5°E	88°to E	4.7	2.3	Dolerite
81	N20°E	90°	1.8	1.3	Dolerite
82	N70°W	90°	3.2	1.5	Aplite
83	N80°E	90°	4.7	2.5	Aplite (barite bearing)
84	N80°W	83°to S	10.9	2.1	Dolerite
85	N80°E	85°to N	9.6	3.1	Andesite
86	N85°E	80°to N	6.6	3	Aplite (feldspar bearing)
87	N80°E	80°to S	6.8	1.4	Aplite (feldspar bearing)
88	N60°W	80°to NE	6.4	3.4	Rhyolite
89	N30°W	74°to N	5.4	1.1	Andesite
90	N60°W	90°	6.8	2.9	Basalt
91	N58°E	80°to N	4.1	3.5	Andesite
92	N5°E	90°	3.2	2.5	Andesite
93	N80°W	80°to N	3.6	1.9	Dolerite
94	N78°E	90°	3.2	2.9	Dolerite
95	N85°E	90°	6.4	2.1	Dolerite
96	N80°W	90°	3.9	3.6	Dolerite
97	N5°E	69°to W	2.7	1.1	Dolerite
98	N45°W	90°	6.1	1.8	Aplite
99	N45°W	90°	8.7	2.4	Aplite
100	N30°E	90°	8.6	1.7	Andesite

The mafic dykes are represented by basalt and dolerite. They are of three main trends N35°W, N5°E and N85°W. From the length and number proportions, it is indicated that the mafic dykes trending N35°W are shorter in length than those trending N85°W. The mafic dykes are fine to medium-grained sometimes porphyritic, black to dark greenish grey in colour. They generally form deep elongated trenches when cutting younger granite and form high peaks when cutting all other rocks with a characteristic onion weathering (Figs. 3a and 3b).

The intermediate dykes are represented by andesite. They are of two main trends N35°W and N85°E as well as three minor trends (N35°E, N55°E and N5°E. They are commonly greenish grey, fine-grained, sometimes highly altered. They are of the same topography as the surrounding rocks (Fig. 3c).

The felsic dykes are mainly represented by rhyolite, aplite and quartz-feldspar porphyry. They are of three main trends N45 E, N85 E and N45 W. They form prominent ridges (Fig. 3d) along all rock units in the area and are commonly yellow, buff or pink in colour, fine-grained or porphyritic, hard and compact. They were intruded at different periods as some of them cut each other.

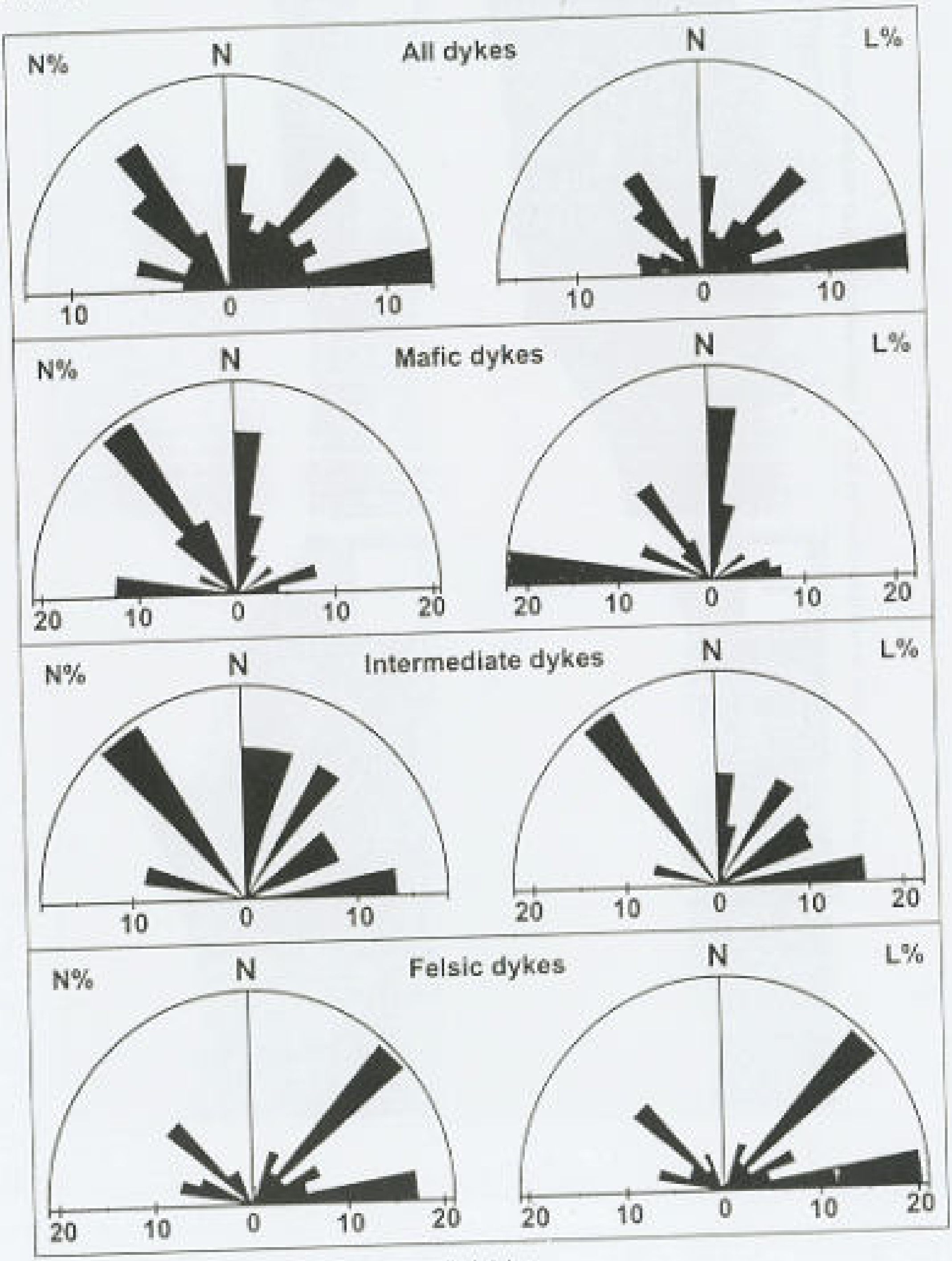

Fig.2: Directional trend analysis of the studied dykes

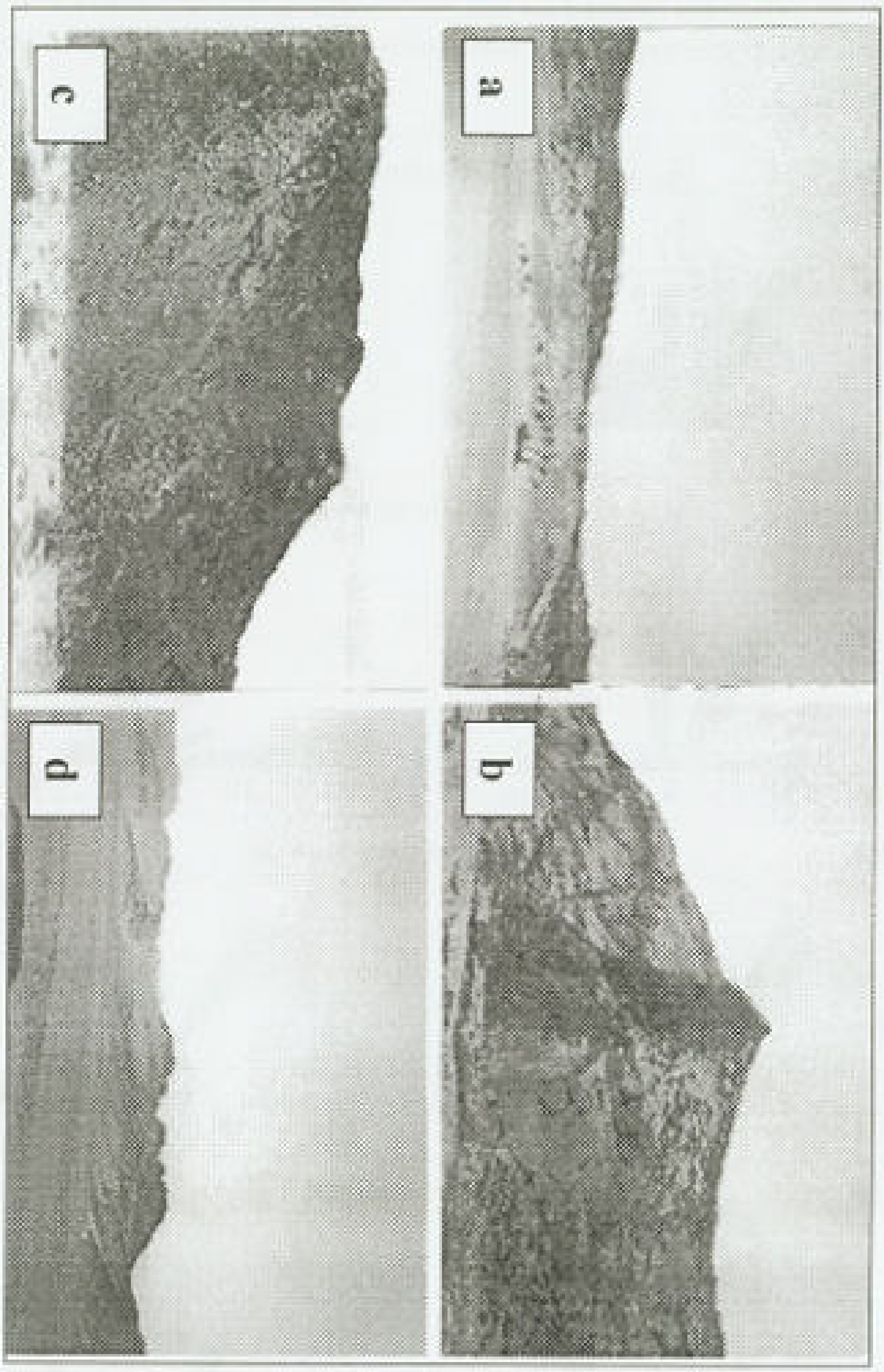

Fig. 3: Field characteristics of the studied mafic (a and b), intermediate (c) and felsic (d) dykes

3- PETROGRAPHY

3.1. Mafic dykes (basalt and dolerite dykes)

Both mafic types are holocrystalline consisting essentially of plagioclase, augite and hornblende as essential minerals. Plagioclase occurs as subhedral laths (up to 2.5 mm in length and 0.4 mm in width in dolerite) twinned according to the albite law and sometimes altered to saussurite. Some plagioclase crystals show conspicuous zoning with altered cores and fresh rims. Some elongated needle-shaped plagioclase arranged in fan or radial arrangement forming open spherulitic texture suggest their formation by devitrification of glass (Srivastava and Sinha, 2004). Augite occurs as large crystals sometimes altered to chlorite. They usually fill the interstitial spaces between plagioclase triangles forming the characteristic ophitic and subophitic textures (Fig. 4a). Hornblende occurs as subhedral prismatic strongly pleochroic crystals. Apatite forms minute prismatic crystals, with six-sided cross sections, generally engulfed in essential minerals. Sphene is rare, occurring as rhombic grains within the hornblende and augite crystals. Chlorite and calcite are secondary minerals. Sometimes, basalt exhibits porphyritic (Fig. 4b) and amygdaloidal textures. The amygdales are filled with quartz, calcite and opaques.

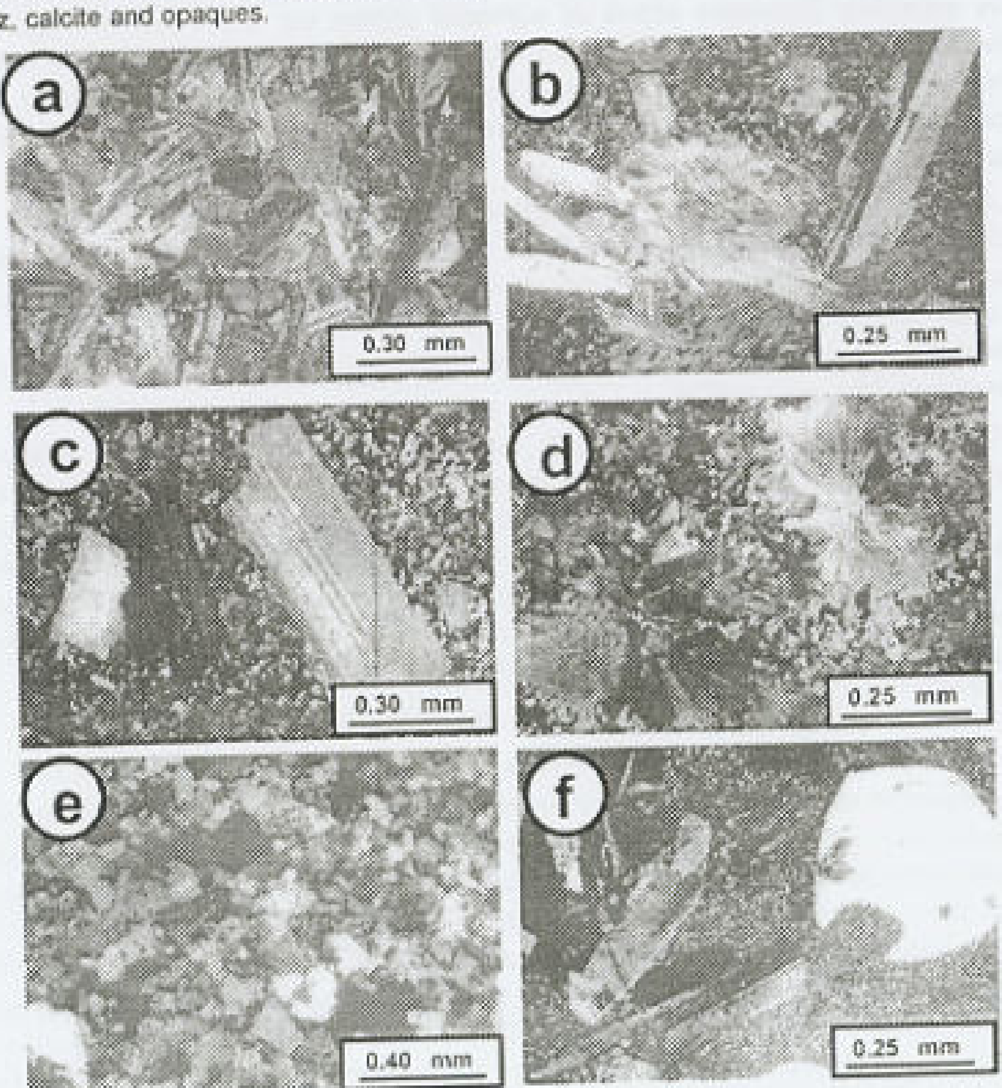

Fig. 4: Petrographic characteristics of the studied mafic (a and b), intermediate (c) and felsic (d,e and f) dykes

3.2. Intermediate dykes (andesite dykes)

The intermediate dykes are mainly represented by andesite that composed of plagioclase and hornblende phenocrysts embedded in very fine groundmass (Fig. 4c) of plagioclase microlites, chlorite and opaques together with hornblende, biotite and quartz. Plagioclase phenocrysts occur as large prisms partly to completely altered to zoisite, epidote and chlorite. They are commonly arranged with the ferromagnesian minerals, with their long axis, parallel to subparallel to each other forming the characteristic fluidal texture. Hornblende is observed as subhedral faintly pleochroic crystals, with occasional alteration to chlorite especially along their cleavage planes and peripheries. Sometimes, the minerals in the groundmass exhibit pilotaxitic texture.

3.3. Felsic dykes (rhyolite, aplite and quartz-feldspar porphyry)

Rhyolite dykes essentially consist of quartz, orthoclase, plagioclase and biotite embedded in a fine-grained groundmass exhibiting micrographic and spherulitic textures (Fig. 4d). The accessory minerals are represented by apatite and zircon. Sericite, chlorite, kaolinite are secondary minerals. Quartz occurs as anhedral crystals (0.3 to 0.5 mm in diameter) exhibiting wavy extinction. Orthoclase occurs as subhedral crystals (up to 0.4 mm in length) partly altered to kaolinite and sometimes perthitized. Plagioclase occurs in minor amount as euhedral crystals (up to 0.4 mm in length) commonly twinned, zoned and sericitized. Biotite occurs as anhedral flakes (up to 0.5 mm across) strongly pleochroic and partly to completely altered to chlorite.

Aplite dykes are composed of equigranular aggregates (Fig. 4e) of quartz and alkali feldspars together with little biotite. Zircon, apatite and rare fluorite and barite occur as accessory minerals. Chlorite and sericite are secondary minerals. Quartz and feldspars occur in equal amount. Quartz occurs as small equant subhedral to anhedral crystals. Alkali feldspars are represented by orthoclase and albite, occurring as small anhedral crystals altered to sericite and kaolinite.

Quartz-feldspar porphyry dykes are composed of phenocrysts of quartz, plagioclase, little orthoclase and biotite set in a very fine groundmass of the same composition. Quartz is the dominant phenocryst usually corroded with the groundmass components forming amoeboid shapes (Fig. 4f). Plagioclase occurs as subhedral laths commonly twinned according to the albite law and sometimes showing oscillatory zoning. Biotite occurs as chloritized phenocrysts with characteristic pleochroism from dark yellow to pale brown. Chlorite, sericite and calcite are secondary minerals.

4- OPAQUE MINERALOGY

4.1. Mafic dykes (basalt and dolerite dykes)

The amount of opaques is about 9% of the total volume of the rock. They are represented by ilmenite and magnetite in equal amounts. Ilmenite occurs as a homogeneous single phase, containing an appreciable amount of Fe_2O_3 in solid solution (ferriilmenite). This is supported by its paler colour and lower bireflection. It forms euhedral to subhedral phenocrysts (0.1-0.4 mm across) as well as minute discrete grains in the groundmass. Ilmenite is frequently replaced by sphene. Magnetite occurs as homogeneous single phase Ti-bearing variety (titanomagnetite) free of any exsolution lamellae. This is supported by its darker colour than Ti-free variety. Magnetite ranges in size from 0.1 to 0.4 mm across exhibiting octahedral habit (Fig. 5a). It is slightly altered to martite particularly along the (111) planes. The majority of the magnetite crystals are extensively replaced by sphene supporting its composition as a Ti-bearing variety. Sometimes, ilmenite occurs in juxtaposition with magnetite forming composite grain (Fig. 5b). Sulphides occur in minor amount (~30% of the opaques) as idiomorphic cubes of pyrite, which is commonly replaced by goethite-"limonite" colloform intergrowth (Fig. 5c).

4.2. Intermediate dykes (andesite dykes)

The amount of opaques is about 7% represented by magnetite and ilmenite as well as traces of pyrrhotite (~5% of the opaques). Magnetite (magnetite / magnetite + ilmenite ratio=0.7) occurs as large crystals as well as minute discrete and skeletal grains in the groundmass. It is extensively altered to martite. Ilmenite forms phenocrysts partly to completely replaced by sphene. Ilmenite also occurs in the groundmass as small prisms arranged in preferred orientation forming flow texture (Fig. 5d).

4.3. Felsic dykes (rhyolite, aplite and quartz-feldspar porphyry dykes)

The amount of opaques in these rocks is about 3%. Ilmenite is the main opaque mineral, whereas magnetite and pyrite occur in very subordinate amounts (Fig. 5e). Ilmenite occurs as homogeneous single phase ferriilemenite. It forms subhedral large crystals sometimes corroded by silicates. Ilmenite ranges in size from 0.1 to 0.2 mm in diameter. It is frequently replaced by sphene and anatase (Fig. 5f). Magnetite (magnetite/magnetite+ilmenite ratio=0.2) occurs in minor amount as fine grains restricted to the groundmass partly to completely martitized. It ranges in size from 0.01 to 0.05 mm across. Pyrite also occurs in minor amount (~10% of the opaques) forming small euhedral crystals commonly altered to goethite.

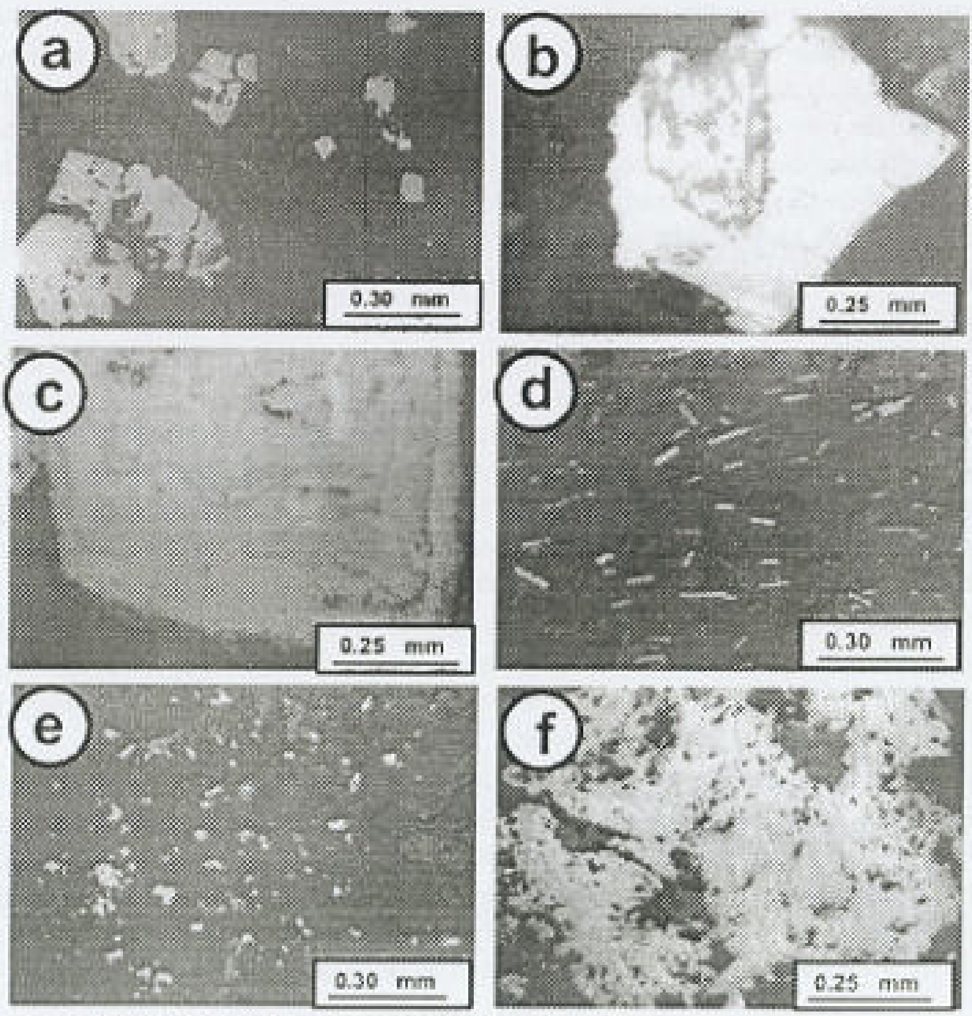

Fig. 5: Characteristics of opaque minerals in the studied dykes

5- GEOCHEMISTRY

Sixteen samples representing the studied dykes were selected in order to identify their geochemical classification and magma type. The major elements were determined using wet chemical analysis technique (Shapiro and Brannock, 1962). The trace elements were determined using XRF technique (Phillips PW 1410 together with a MO-target tube operated at 50 kV and 30 mA). The equivalent uranium (eU) and equivalent thorium (eTh) contents were determined in the field by measuring the gamma-activity of their daughter elements using a portable gamma-ray spectrometer (model GS-256). The results of analyses are given in table (2).

Geochemical classification of the studied dykes was attempted using Le Bas et al. (1986) and Le Maitre (1989) diagrams (Figs.6a and 6b respectively). Accordingly, the mafic dykes could be classified as basalt. The intermediate dykes are classified as andesite and trachy-andesite. The acidic dykes plot in the rhyolite field, except aplite dykes which plot in the dacite field. Furthermore, the K_2O-SiO_2 variation diagram (Le Maitre, 1989) illustrates the potassic nature of volcanic rocks. It is evident that the studied mafic dykes exhibit low- to medium-potassic affinity (Fig. 6b), while the intermediate dykes exhibit medium- to high-potassic tendency. On the other hand, all types of acidic dykes show high-potassium affinity (Fig. 6b), but aplite dykes show slightly lower potassic tendency.

Total alkalis-silica variation diagram was used by Irvine and Baragar (1971) to discriminate between the alkaline and subalkaline volcanic rocks. This relationship clearly indicates that, the studied rocks plot in the subalkaline field (Fig. 6c). The subalkaline rocks could be further subdivided into calc-alkaline and tholeiitic rocks using AFM diagram (Irvine and Baragar, 1971). The studied doleritic and basaltic dykes fall in the tholeiitic field (Fig. 6d). They appear genetically related to each other and might be derived from the same parental magma (Tarney, 1992 ; Le Maitre, 2002 and Srivastava and Sinha, 2004) but they cut each other in the field which might suggest successive periods of generation.

Equivalent uranium and equivalent thorium contents increase gradually from mafic through intermediate to felsic dykes. Among the types of felsic dykes, the rhyolite dykes show the highest eU and eTh contents reaching up to 16.2 and 33.9 ppm respectively. These rhyolites could be classified as uraniferous rocks as suggested by Darnley (1982) for granites containing uranium at least twice the Clarke value (4 ppm). In addition, the uraniferous rocks are characterized by Zr/Sr ratios greater than 1.65 (Hall and Walsh, 1969). Accordingly, the studied rhyolite could be considered as uraniferous rock as it possesses uranium contents greater than 14 ppm and shows Zr/Sr ratios greater than 1.8.

In fact, Th is considered to be a relatively immobile element; in other words it resists redistribution by the chemical weathering and alteration processes to a great extent. Thus, the wide range of eTh (8.7 and 33.9 ppm) in the studied felsic dykes (Table 2) may suggest that these dykes are related to different magmas.

Normally, thorium is three times as abundant as uranium in igneous rocks (Rogers and Adams, 1969). When this ratio is disturbed, it indicates a depletion or enrichment of uranium during post magmatic processes while thorium is rather stable for mobilization (Cuney, 1984 and El-Mansi and Dardier, 2005). In this work, the eTh/eU ratio for rhyolite is less than 2.1 (Fig. 6e), indicating that rhyolitic dykes suffered post magmatic processes, which cause addition of uranium along fractures and alteration zones (especially hematitized spots).

Table (2): Major oxides (wt %) and trace elements (ppm) analyses of the studied dykes

Rock type	Mafic dykes					Intermediate dykes					Felsic dykes					
	Basalt			Dolerite		Andesite and trachy-andesite					*QFP		Aplite		Rhyolite	
Sample No.	76	78	90	19	96	21	46	56	60	67	33	65	82	83	26	88
Symbol	Λ	Λ	Λ	●	●	♦	♦	♦	♦	♦	o	o	+	+	x	x
Major oxides (wt%)																
SiO_2	50.12	49.12	51.42	49.64	51.55	59.07	60.73	59.94	56.92	61.57	73.93	74.16	64.74	66.92	72.83	74.12
TiO_2	0.42	0.33	0.76	0.84	0.53	0.88	0.58	1.05	1.13	0.44	0.20	0.27	0.72	0.34	0.26	0.25
Al_2O_3	16.39	15.93	15.00	14.78	14.07	15.55	14.62	14.93	16.73	14.53	11.51	11.73	14.04	12.89	12.44	12.71
Fe_2O_3	2.30	3.07	2.05	3.02	2.01	4.79	3.58	4.86	4.81	3.35	1.31	0.26	2.43	1.97	1.80	1.35
FeO	11.17	14.15	12.31	11.89	12.14	2.48	2.21	2.27	2.66	2.29	0.25	0.31	1.72	1.68	0.72	0.45
MnO	0.15	0.22	0.17	0.22	0.12	0.32	0.2	0.15	0.3	0.21	0.34	0.05	0.62	0.74	0.06	0.06
MgO	6.61	5.13	6.67	6.95	6.54	3.93	3.27	3.33	3.72	3.16	0.68	0.51	0.71	0.52	0.89	0.72
CaO	8.05	6.35	6.14	7.53	8.27	5.28	4.57	4.68	5.17	4.35	1.05	1.44	6.11	5.44	1.57	1.41
Na_2O	2.11	2.74	2.12	1.78	1.46	3.49	4.02	3.47	3.31	4.23	3.54	3.62	3.03	3.31	3.81	3.51
K_2O	0.27	1.01	0.51	0.63	0.61	2.04	3.78	2.09	1.93	3.45	4.33	4.51	3.01	3.32	4.49	4.24
P_2O_5	0.10	0.16	0.19	0.13	0.07	0.30	0.27	0.25	0.15	0.27	0.04	0.03	0.23	0.37	0.04	0.04
L.O.I.	2.17	1.58	2.49	2.48	2.62	1.53	2.07	2.66	2.82	2.07	2.71	2.96	2.54	2.08	0.77	1.01
Total	99.86	99.79	99.83	99.89	99.99	99.68	99.90	99.68	99.85	99.92	99.89	99.85	99.90	99.78	99.86	99.87
Trace elements (ppm)																
Rb	29	63	31	44	32	72	110	63	59	87	100	112	86	99	156	134
Ba	328	403	298	317	428	518	601	403	397	563	239	305	976	823	399	301
Sr	298	276	355	409	327	301	297	369	227	132	89	52	128	136	58	74
Zr	21	17	9	36	25	64	107	57	41	122	80	99	85	98	158	134
Nb	2	2	4	2	3	3	6	2	4	6	8	10	10	14	28	15
eU	1.5	2.1	1.6	1.3	1.8	3.4	4.0	2.3	2.0	3.6	5.2	8.1	6.2	4.9	16.2	14.5
eTh	3.0	2.9	5.1	4.8	6.2	8.1	9.6	5.4	8.8	10.5	14.3	12.8	10.9	8.7	33.9	28.8

* QFP = Quartz feldspar porphyry

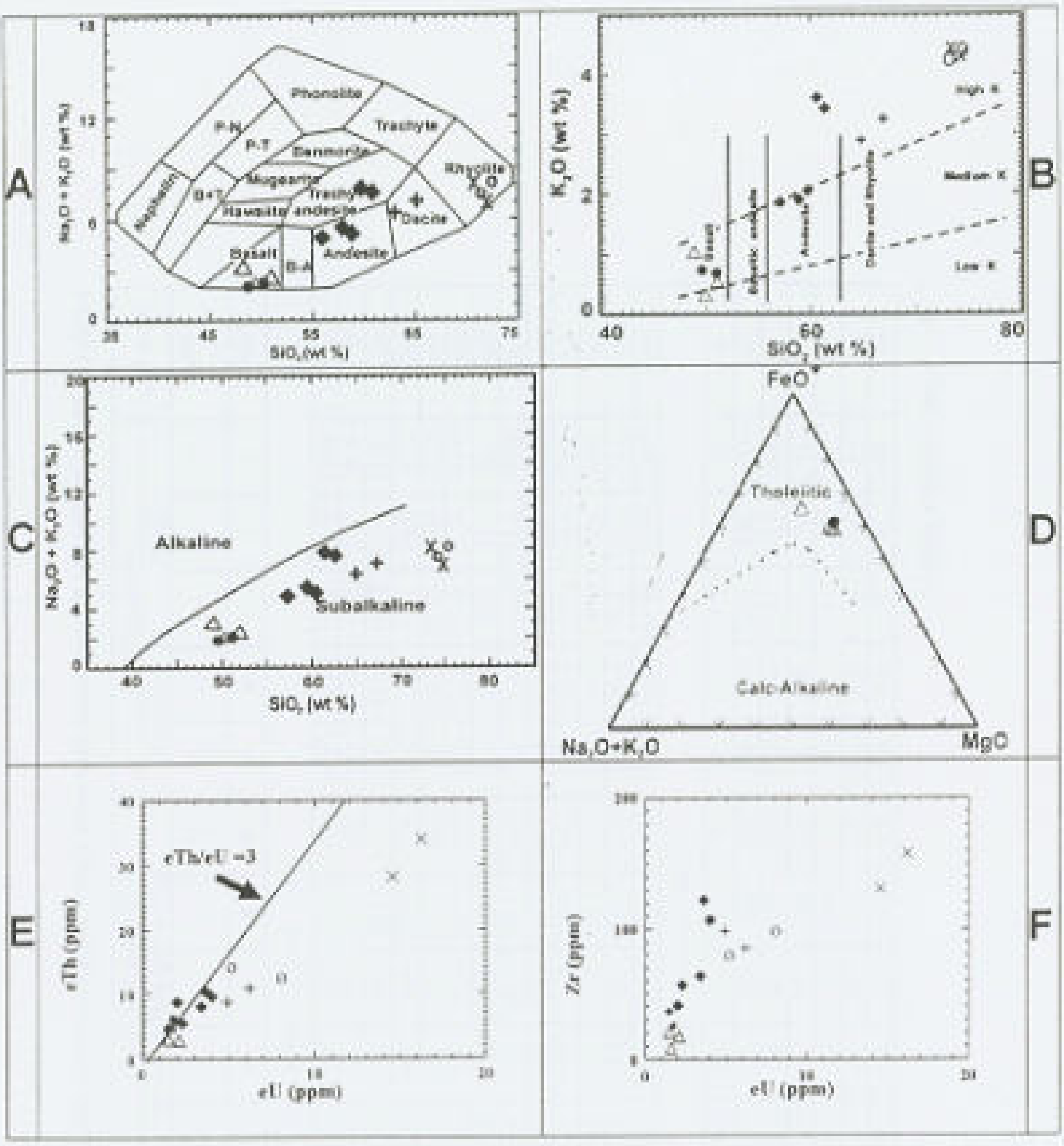

Fig.6: Geochemical characteristics of the studied dykes

The studied rhyolite possesses high Zr contents (> 150 ppm), suggesting that this rock is rich in zircon. The relationship between U and Zr in studied rhyolite is positive (Fig. 6f), indicating that uranium distribution is mainly controlled by magmatic processes where U is trapped in the crystal lattice of zircon (Read, 1984 ; Deer et al., 1992 and El-Mansi et al. 2003).

6-CONCLUSIONS

Wadi Hafiya area (~648 km^2) is located between latitudes 24° 51' and 25° 02' N and longitudes 33° 59' and 34° 17' E. It is dissected by numerous dykes of different types, trends, lengths and thicknesses. One hundred of major dykes are traced and mapped. The mapped dykes are of three main types namely mafic, intermediate and felsic; their main characteristics are summarized in table (3).

The characteristics of these dykes and the cross-cutting relationships between them indicate that these dykes were intruded during at least four successive periods, each is characterized by a group of dykes having nearly the same mineralogical compositions. These periods are represented by generation of old mafic dykes followed by intermediate ones and then felsic ones and finally other mafic dykes.

Table (3): Comparison between the different types of dykes dissecting Wadi Hafiya area

		Mafic dykes	Intermediate dykes	Felsic dykes
Field characteristics	Topography	Slightly negative and shallow trench if cutting younger granites	The same as the host rocks	Ridges and high peaks
	Length	Up to 10.9 km with an average 3.5 km	Up to 9.6 km with an average 4.3 km	Up to 8.7 km with an average 3.6 km
	Width	1.1 to 5.6m with an average 1.5m	1.1 to 3.6m with an average 2.4m	1 to 4.3m with an average 1.7m
	Main trend	N35°W, N5°E and N85°W	N35°W and N85°E	N45°E, N85°E and N45°W
Petrography	Rock Name	Basalt and dolerite	Andesite and trachy-andesite	Rhyolite, aplite and quartz-feldspar porphyry
	Essential minerals	Plagioclase, augite, hornblende	Plagioclase and hornblende	Quartz, orthoclase, plagioclase and biotite
	Accessory and secondary minerals	Apatite, sphene, chlorite, epidote, calcite	Orthoclase, zoisite chlorite and epidote	Apatite, zircon, sphene, chlorite, sericite, kaolinite, calcite, barite and fluorite
	Textures	Ophitic, sub-ophitic, little porphyritic and amygdaloidal	Porphyritic and pilotaxitic	Porphyritic, spherulitic and granophyric
Opaque mineralogy	Total opaques	9%	7%	3%
	Minerals	Ferriilmenite, titanomagnetite and pyrite	Magnetite, ilmenite and pyrrhotite	Ilmenite, magnetite and pyrite
	Magnetite/ Magnetite+ilmenite	0.5	0.7	0.2
	Sulphides/ sulphides+ oxides	0.3	0.05	0.1
	Textures	Discrete crystals and composite grains	Discrete subhedral crystals	Discrete subhedral to anhedral crystals
	Secondary minerals	Martite, sphene and goethite	Martite and sphene	Martite, sphene and goethite and anatase
Geochemistry	Magma type	Low- to medium- K tholeiitic	Medium- to high- K subalkalic	High-K subalkalic
	eU	1.5-2.1 (ppm) with an average 1.41	2-4 (ppm) with an average 3.06	4.9-15.2 (ppm) with an average 9.18
	eTh	2.9-6.2 (ppm) with an average 3.66	5.4-10.5 (ppm) with an average 8.48	8.7-33.9 (ppm) with an average 18.23

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جيولوجية والتركيب المعدنى وجيوكيميائية الجدد القاطعة لمنطقة وادى حافيه، بالصحراء الشرقية، مصر

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يقطع فى منطقة وادى حافيه عدد هائل من الجدد (القواطع) والعروق ذات التركيب المختلف. فى هذه الدراسة، يبلغ عدد الجدد الرئيسية التى تم تتبعهم بالتفصيل فقط مائة قاطع رئيسى حيث تم تسجيل خطوط مضربهم وأطوالهم وسمكهم و ميولهم وكذلك تم دراسة الخصائص البتروجرافية والمعادن المعتمة وجيوكيميائية هذه الجدد أيضاً. ومن ثم أمكن تصنيف الجدد المدروسة إلى ثلاث مجموعات: مافية ومتوسطة وفلسية.

تتمثل الجدد المافية بصخرى البازلت والدوليريت والتى تأخذ ثلاثة إتجاهات رئيسية: شمال ٣٥° غرب و شمال ٥° شرق وشمال ٨٥° غرب. متوسط أطوالهم ٣,٥ كيلومتر وعادة ما تظهر هذه المجموعة طوبوغرافية سلبية بالنسبة للصخور المضيفة المحيطة. بتروجرافياً، هذه المجموعة لها نسيج أوفيتى ودون الأوفيتى. أما النسيج البورفيرى فهو نادر. كما تبلغ نسبة المعادن المعتمة بها (حوالى ٩٪ من الصخر) متمثلة بمعادن إلمنيت وماجنيتيت وبيريت. علاوة على أنهم نشأوا من ماجما ذات طبيعة توليتية قليلة إلى متوسطة البوتاسيوم.

أما الجدد المتوسطة فتتمثل بصخر الأنديزيت ونادراً تراكى-أنديزيت والتى تتواجد فى إتجاهين رئيسيين هما: شمال ٣٥° غرب وشمال ٨٥° شرق. متوسط أطوالهم ٤,٢ كيلومتر وعادة ما تظهر هذه المجموعة نفس الطوبوغرافية مثل الصخور المضيفة المحيطة. بتروجرافياً، هذه المجموعة لها نسيج بورفيرى و بيلوتاكسيتى. كما تبلغ نسبة المعادن المعتمة بها (حوالى ٧٪ من الصخر) متمثلة بمعادن ماجنيتيت و إلمنيت وبيروتيت ونشأت هذه المجموعة من ماجما ذات طبيعة دون القلوية متوسطة إلى عالية البوتاسيوم.

أما الجدد الفلسية فتتمثل بصخور الرايولايت والأبليت والكوارتز- فلسبار بورفيرى وهى تتواجد فى ثلاثة إتجاهات رئيسية: شمال ٤٥° شرق وشمال ٨٥° شرق علاوة على شمال ٤٥° غرب. وعادة ما تظهر هذه المجموعة حافات بارزة ومتوسط أطوالهم ٢,٦ كيلومتر. أما المعادن المعتمة بها (حوالى ٢٪ من الصخر) فهى إلمنيت وماجنيتيت وبيريت ونشأت هذه المجموعة من ماجما ذات طبيعة دون القلوية عالية البوتاسيوم.

من الخصائص المختلفة وعلاقات القاطع والمقطوع لهذه الجدد خلصت هذه الدراسة إلى أن هذه الجدد بأنواعها المختلفة تكونت على فترات زمنية مختلفة بدأت بالجدد المافية القديمة تلتها الجدد المتوسطة ثم الجدد الفلسية وأخيراً الجدد المافية الأحدث.