Geologyand Geochemistry of Magmatic Rocks, Gabal Elba Area, South Eastern Desert, Egypt

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Abstract: The magmatic rocks of Gabal Elba area comprise metavolcanics related to early orogenic stage, tonalite, granodiorite and monzogranite related to syn to late orogenic stage and rhyolite porphery, gabbro, alkali granite, syeniteand quartz syenite (Elba ring complex), related to post orogenic stage. The metavolcanics mainly have theolitic affinity, indicating island arc regime. The tonalite, granodiorite and monzogranite have calc-alkaline affinity indicating continental arc regime. The rhyolite porphery, gabbro, alkali granite, syenite and quartz syenite show theolitic affinity for gabbro and alkaline affinity for rhyolite porphery, alkali granite, syenite and quartz syenite, indicating bimodal magma, developed within continental plate and rifting regime to form Elba ring complex.
[Abu El-Leil, H. M. Azzam, M.H. Bekhit, and I.A. El-Shaheed. **Geologyand Geochemistry of Magmatic Rocks, Gabal Elba Area, South Eastern Desert, Egypt.** *Rep Opinion* 2017;9(8):9-27]. ISSN 1553-9873 (print); ISSN 2375-7205 (online). http://www.sciencepub.net/report. 2. doi:10.7537/marsroj090817.02.

Keywords: Geologyand; Geochemistry; Magmatic Rocks; Gabal Elba Area; South Eastern Desert; Egypt

Introduction

Gabal Elba areacovers about 300 km^2 betweenlatitudes 22° 07` to 22° 15` N, and longitudes 36° 15` 40" to 36° 33`E, at the South Eastern Desert (Fig.1). It represents a part of Arabian-Nubian Shield, covered by some Neoproterozoic rocks an addition to some Phanerozoic rocks known as Gabal Elba ring complex.

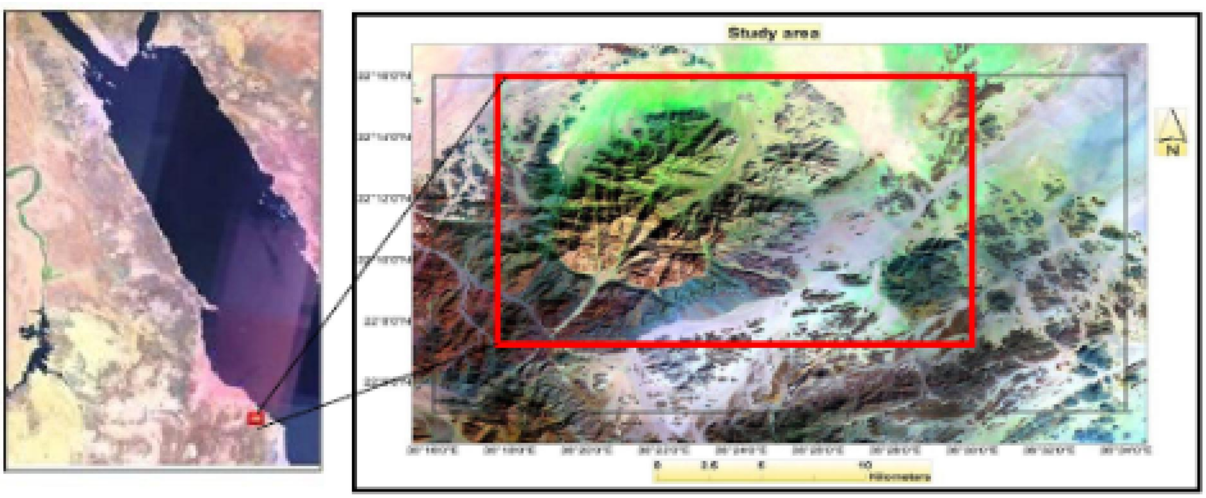
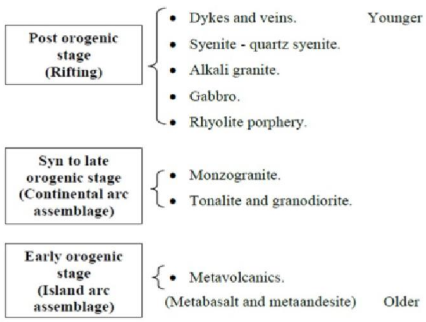


Fig.1: Location map of the study area.

The area under study had been studied by different authors (Hume, 1935, Bassyouni, 1957, Hussein, 1977, El-Bedewy,1993, EL-Alfy et al., 1994, Nasr et al., 1994, Nasr and Youssef, 1995, Khalid et al, 1997, Shahin, 2000).

Elba ring complex is considered as one of famous ring complex in the Eastern Desert of the Pan African Orogenic belt, most of circular alkaline complexes, emplaced in an intercontinental setting within the Arabian-Nubian Shield (El-Ramly and Hussein, 1985, Harris,1985, Vail, 1985). Moreover, the occurrence, tectonic environment and geochronology of the Egyptian ring complexes have been reviewed by several authors (El-Ramly et al., 1969 and 1971, Hashad et al., 1979, Dc Gruyter and Vogel, 1981, Serencsits et al., 1979, El-Ramly and Hussein, 1985). However, four groups of Phanerozoic ring complexes have identified. The first of Paleozoicage (404±8 Ma), the second Permo -Triasic (230-200 Ma), the third of Late Jurassic-Early Cretaceous, (160- 120 Ma), and thefourth of Late Cretaceous age (100-80 Ma) (Serencsits et al. 1979, Hashad and El-Ramly, 1979, Meneisy and Kreuzer 1974).

Geology



According tofield observationsand given new geologic map (Fig. 2), the examined rock units of Gabal Elba area are related to three tectonic stages, known asearly orogenic stage of island arc assemblage, syn to late orogenic stage of continental arc assemblage and post orogenic stageofrifting assemblage. The three stages comprise different rock units that arranged from older to younger according the sequence.

Early orogenic stage (Island arc assemblage)

The early orogenic stage comprisesmetavolcanics of Island arc assemblage, forming low to moderate hills at the western part of the mapped area (Fig. 3), they are metabasalt and metaandesite, directly cut by the alkali granite, syenite and quartz syenite of Gabal Elba ring complex, as well as tonalite and granodiorite at Wadi Serimtai (Fig. 4 & 5).

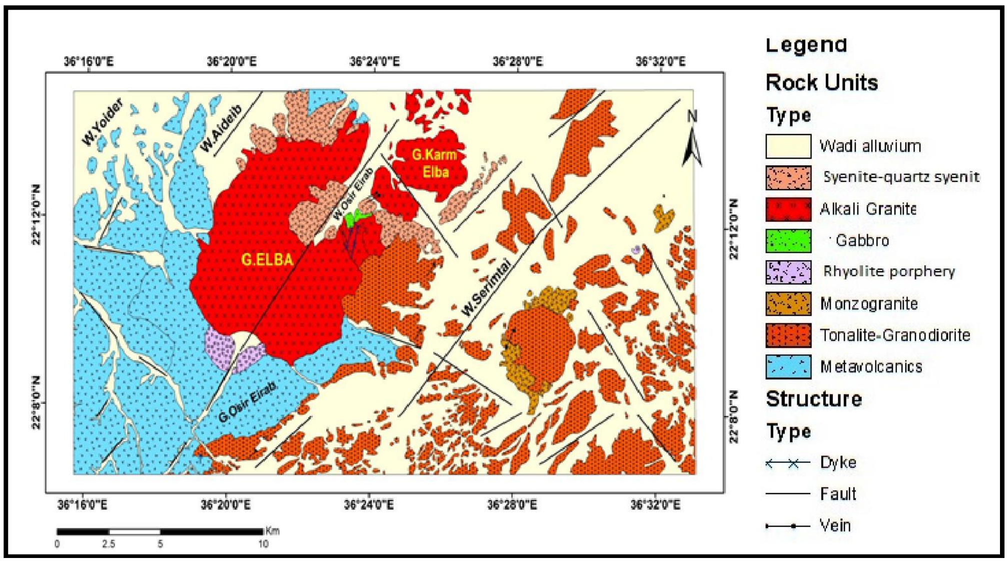


Fig.2: Geologic map of Gabal Elba area (modified after Nasr et.al. 1994).

Syn to late orogenic stage (Continental arc assemblage)

The syn to late orogenic stage of Continental arc assemblage comprises essentially I-type granitoids of tonalite, granodiorite and monzogranite. The tonalite and granodiorite occur as an elongated NE – SW small massive rocks, highly weathered with characterized exfoliationas well as they enclose some xenoliths (Fig. 6). They are intruded by alkali granite (Fig. 7) and some basic dykes. On the other hand, the tonalite and granodiorite rocks intrude directly the metavolcanics with sharp obvious contact. In turn, they directly intrude the metavolcanics with sharp obvious contact.

The monzogranite is represented by small mass along Wadi Serimtai at the east of Gabal Elba, directly intruding the tonalite and granodiorite (Fig. 8). On the other hand, it is traversed by some quartz veins, particular in NE-SW.

Post orogenic stage (Rifting)

The Post orogenic stage (Rifting) comprises mainly the youngest rock units of Gabal Elba ring complex, is composed essentially ofrhyolite porphery, gabbro, alkali granite and syenite - quartz syenite.

The rhyolite porphery represents the older rock units of Elba ring complex, cropping out at south of the ring complex, as small mass of moderate to relatively high relief (Fig. 9), usually of porphyritic texture, sometime associating with some pyroclastic sheets (Fig. 10). The rhyolite porphery and associated pyroclastic sheets directly invade the metavolcanic, as well as they are directly cut by the alkali granite.

The gabbro represents the second member of the rock units of Elba ring complex. It is represented by small mass at the north of Gabal Elba along Wadi Osir Eirab (Fig. 11). Itoccurs as sub-rounded mass, directly cut by the alkali granite and syenite-quartz syenite.

The alkali granite representsthe third member of the ring complex. It occurs as sub- rounded plutons forming up the main bulk of Gabal Elba ring complex and characterized by cavernous shape (Fig. 12), divided by NE-SW fault along Wadi Osir Eirab. Field study indicated that the alkali granite has younger age than the rhyolite porphery and gabbro, which directly cut by them, as well as some basic dyke swarmsand quartz veins.

The syenite – quartz syenite appear as low to moderate jointing semicircular exposures (Fig. 13) surrounding the northern part of Gabal Elba alkali granite pluton. They are representing the younger rock member of Elba ring complex, which directly cut the alkali granite.

Fig.3 Moderate hill of joined metavolcanics.

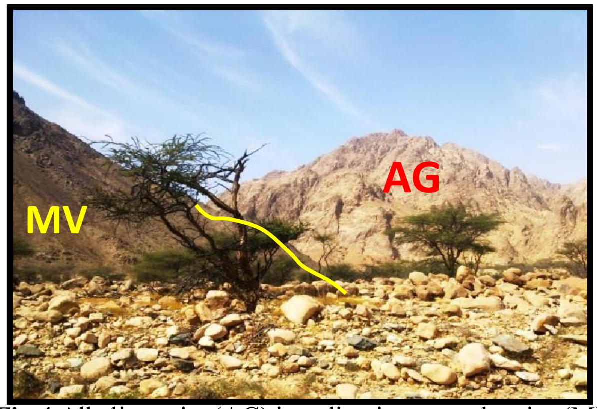


Fig.4 Alkali granite (AG) invading in metavolcanics (M)

Fig.5 Sharp intrusive contact between metavolcanic (MV) and quartz syenite (Sy).

Fig.6 Mafic xenoliths in tonalite.

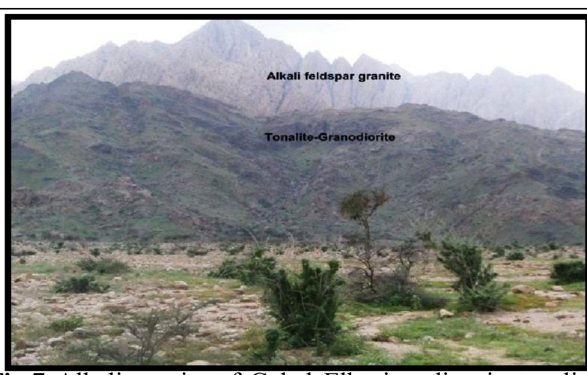


Fig.7 Alkali granite of Gabal Elba invading in tonalite-granodiorite.

Fig.8 Contact between monzogranite and tonalite.

Fig. 9 Medium relief of rhyolite porphery (Rh) at south of Gabal Elba and shows metavolcanic (MV) and alkali granite (AG).

Fig.10 Laminations of rhyolite porphery.

Fig. 11 Contact between gabbro and syenite - quartz syenite.

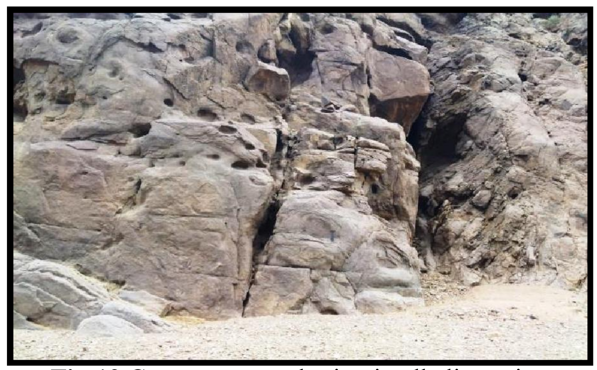


Fig.12 Cavernous weathering in alkali granite.

Fig.13 Jointing in syenite - quartz syenite.

E Petrography

arly orogenic stage (Island arc assemblage)

The early orogenic stage of island arc assemblage comprises the metabasalt and metaandesite composition. The metabasalt is fine grained rock composed essentially of plagioclase and augitein addition to some actinolite, chlorite, biotite, and carbonate as secondary minerals. Plagioclase (An_{38} - An_{55}) occurs either as fine grained or porphyroblast crystals (Fig. 14) covering about 52.5% of rock composition. Augite occurs asreacted rounded to sub-rounded crystals covering about 17.5% of rock composition, partially or totally altered to iron oxides, actinolite and chlorite.

The metaandesite is fine grained rock, displaying porphyroblast and schistose textures. It consists mainly of plagioclase up to (60%), hornblende (14.5%), biotite (12.5%), and quartz (6.5%), with some secondary chlorite, actinolite and iron oxides. The Plagioclase (An_{30} - An_{40}) is the most common mineral (Fig. 15), represented by idiomorphic and sub – idiomorphic crystals, partially to totally altered, whereas their twining are masked. Hornblende occurs as pale green crystals partially altered to chlorite. Biotite occurs as flaky crystals, often with dark brown pleochroism. Quartz occurs either as porphyroblast deformed or fine crystals distributing overall the rock mineral constituents.

Syn to late orogenic stage (Continental arc assemblage)

Tonalite

The tonalite is a coarse-grained equigranular rock, composed essentially of plagioclase, quartz, hornblende and biotite in addition to minor amount of alkali feldspars. Iron oxides and allanite are the accessory minerals.

Plagioclase is the dominant (53%) of mainly oligoclase (An_{20}-An_{30}) and less common andesine (An_{30}– An_{40}). It display compositional zonation and lamellar twinnings, (Fig. 16), partially altered to sericite. Hornblende occurs as prismatic elongated crystals strongly pleochroic to green and deep green color, often associated with some iron oxides. Biotite is less common, represented by pale brownish flaky crystals pleochroic often to deep brown color. Alkali feldspars are less common, represented by orthoclase and orthoclase-perthite, covering about 4.5% of the rock mineral constituents.

Granodiorite

The Granodiorite is medium to coarse-grained rock, composed essentially of plagioclase (35%), quartz (30%), alkali feldspars (15.44%), biotite and hornblende (13.12%). In addition to allanite, sphene, zircon, apatite and iron oxides as accessory minerals.

Plagioclase is mainly oligoclase (An_{10}-An_{30}), represented by euhedral and subhedral crystals, twinned often of albite - carlsbad twinnings, sometimes of compositional zonation, (Fig. 17). Quartz occurs as medium tocoarse-grained crystals, commonly displaying wavy extinction and filling the interstitial spaces of the mineral constituents (Fig. 18). Alkali feldspars are mainlymicrocline, microcline - perthite and orthoclase. Microcline is predominant andmicrocline –perthite are less abundant. Biotite, often occurs are prismatic platy crystals, either as separated or aggregated chlorite. Hornblende occurs as subhedral crystals, with characteristic yellowish green and yellowish brown pleochroism, sometimes with abnormal simple twining, (Fig. 19).

Monzogranite

The monzogranite is medium to coarse equigranular rock, composed of considerable alkali feldspar amount (36.33%), quartz (32.67%) and plagioclase (26.67%). Mafic minerals are less common (3%). The monzogranite contains some iron oxides as accessory minerals, epidote and chlorite as secondary minerals.

The alkali feldspars are mainlymicrocline, orthoclase, microcline –perthite and orthoclase perthite. The microcline is relatively abundant. Perthite is mainly of vein type (Fig. 20). Quartz occurs as anhedral crystals often filling the interstitial spaces of mineral constituents (Fig. 21), sometimes as intergrowing fine crystals with microcline and orthoclase to form micrographic and granophyric subordinate textures. Plagioclase of oligoclase (An_{12}-An_{25}), albite is relatively less (An_{10}-An_{15}). Most often, they show carlsbad-albite and percline twinning, as well as zonation (Fig. 22). Biotite and muscovite are percent, whereas biotite is the common mafic minerals obtained as flaky and fine crystals distributed among the rock mineral constituents. Muscovite is represented by fine flaks connected with the alkali feldspars.

Postorogenic stage (Rifting)

Rhyolite porphyry

The rhyolite porphyry is fine-grained rocks of mainly porphyritic texture. It is composed of alkali feldspars (50.67%), quartz (30.33%) and plagioclase (15%). Biotite and iron oxides are the main accessory minerals and chlorite is the secondary mineral.

The alkali feldspars are mainly orthoclase perthite occurring often as big phenocrystals with well-developed simple twinnings and vein-type perthites,. Plagioclase (An_{10}-A_{15}) occurs as anhedral phenocrystals, often with albite lamellar and pericline twinnings. Biotite occurs as fine aggregates partly altered to chlorite and associated with some iron oxides.

Gabbro

The investigated gabbro consists mainly of plagioclase (65.88%), olivine (18.67%) and pyroxene (1.67%), in addition to some hornblende (1.67%) and iron oxides (0.83%). The rock exhibits often ophitic, subophitic and poikilitic textures.

The plagioclase is mainly labradorite ($An_{.50}$-An_{60}), of anhedral and subhedral shapes, showing often albite-carlsbad and pericline twinnings, sometimes they are saussuritized, (Fig.23). Olivine is of considerable amount of pale yellow color, including some iron oxides. Pyroxene minerals are represented by clino-pyroxene and ortho-pyroxene. The clino-pyroxene is mainly augite, represented by anhedral and subhedral crystals, slightly altered to tremolite, actinolite and chlorite. On the other hand, the augite crystals partly or totally enclose some plagioclase to form subophitic and ophitic textures, (Fig.24). Hornblende is uncommon, represented by anhedral and subhedral crystals of green color and deep green pleochroism.

Alkali granite

The alkali granite is coarse-equigranular rock composed of considerable alkali feldspars amount

(60.06%), quartz (37.06%), in addition to little amount plagioclase (0.93%), biotite (0.5%) and aegirine (0.25%).

The alkali feldspars are mainly orthoclase and microcline perthites of patchy and vein-types, associating often with quartz to form sub-ordinate graphic and micrographic textures. Quartz occurs as anhedral crystals, showing often wavy extinction. Plagioclase is mainly albite (An_5-An_{10}), showing often albite lamellar twinning. Biotite is less common, represented by flaky crystals with pale brown color and deep brown pleochroism. Aegirine occurs as anhedral and subhedral crystals, usually with pale brown color and deep brown pleochroism.

Syenite and quartz syenite

The syenites and quartz syenites are coarse-grained rocks, composed mainly of alkali feldspars (54%), quartz (26.5%), plagioclase (14.5%) and biotite (3.5%). Iron oxides are the common accessory minerals.

The alkali feldspars are the abundant minerals, represented by orthoclase, microcline, orthoclase perthite and microcline perthite mainly of patchy and vein types, sometimes, they are surrounded and mantled by thin rims of sodic plagioclase, (Fig.25). Quartz occurs with moderate amount, as medium grained crystals, sometimes as fine-grains intergrowing with the microcline in forming graphic texture. Plagioclase is mainly albite (An_8-An_{18}) of albite twinning and associated with some biotite crystals. Biotite is less common represented by flaky crystals, often associated with some iron oxides.

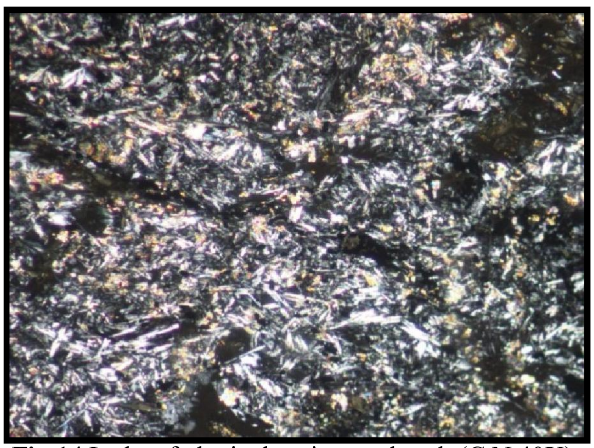


Fig.14 Laths of plagioclase in metabasalt (C.N.40X).

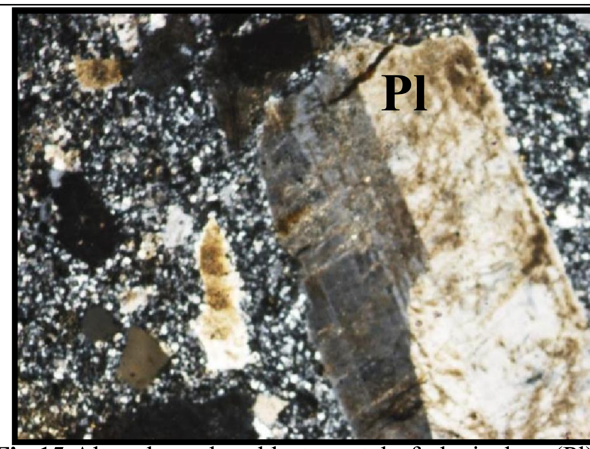


Fig.15 Altered porphyroblast crystal of plagioclase (Pl)in metaandesite (C.N.40X).

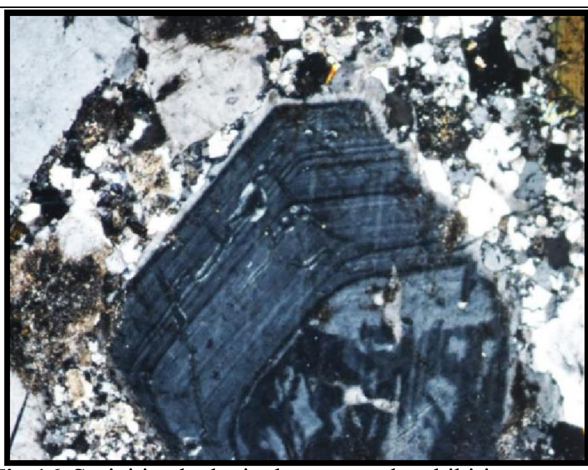


Fig.16 Sericitized plagioclase crystal exhibiting normal zoning in tonalite, (C.N.40X).

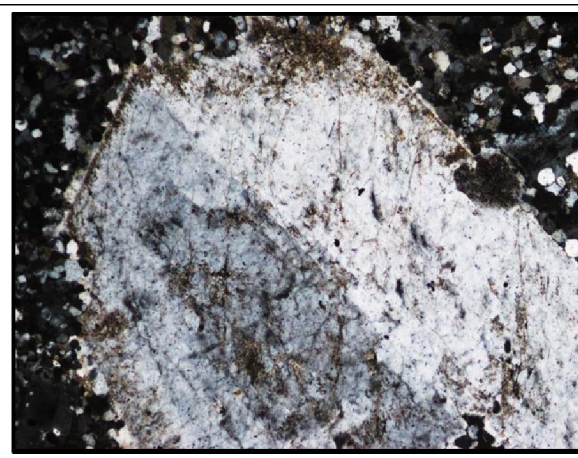


Fig.17 Zoned plagioclase phenocrysts in the granodiorite (C.N.40X).

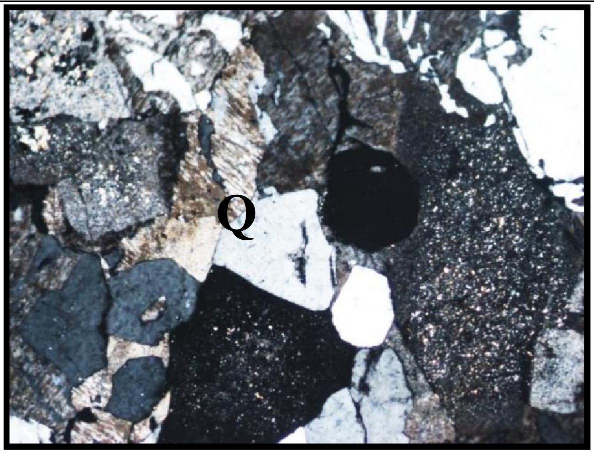


Fig.18 Wavy extension of quartz (Q).

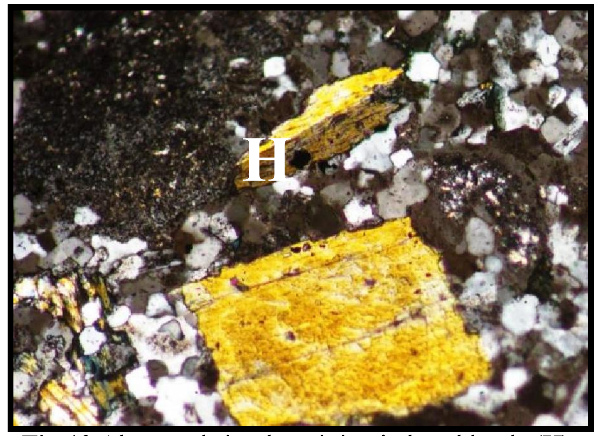


Fig.19 Abnormal simple twining in hornblende (H).

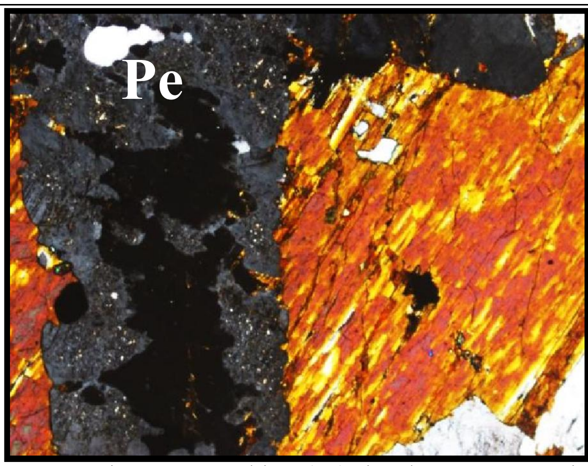


Fig.20 Vein type perthite (Pe) in the monzogranite, (C.N. 40X).

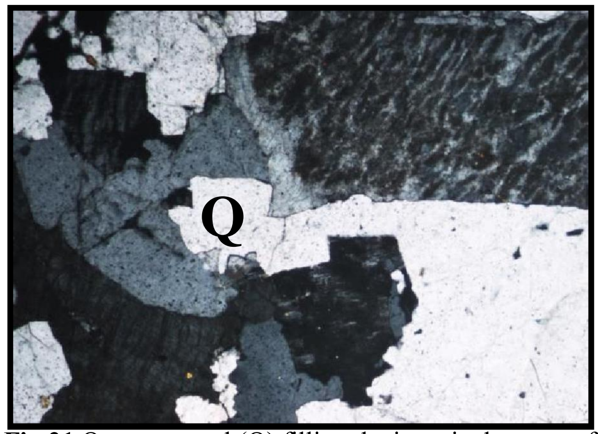


Fig.21 Quartz crystal (Q) filling the intestinal spaces of mineral constituents in the monzogranite, (C.N.40X).

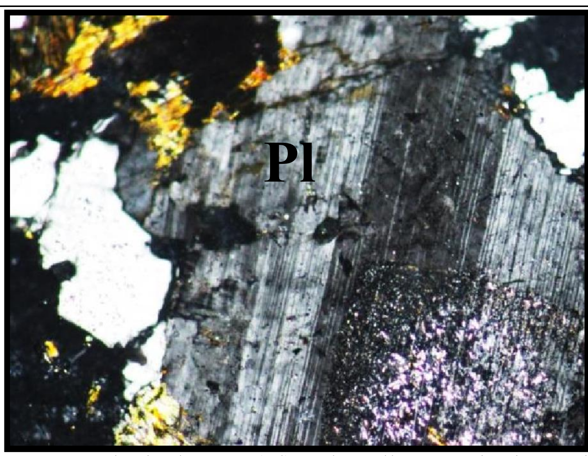


Fig.22 Plagioclase (Pl) lamellar twinning in monzogranite, (C.N.40X).

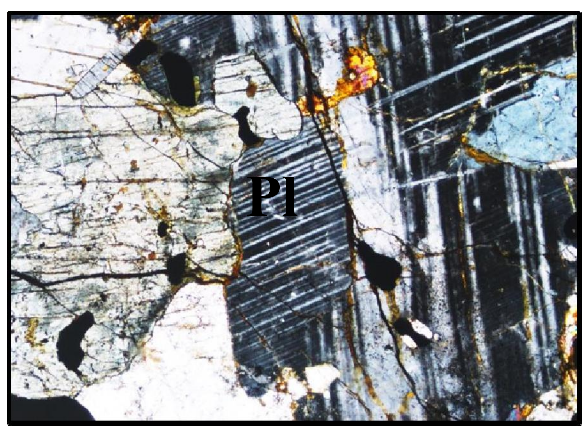


Fig.23 Albite carlsbad, percline twinnings of plagioclase (Pl), in the gabbro (C.N.40X).

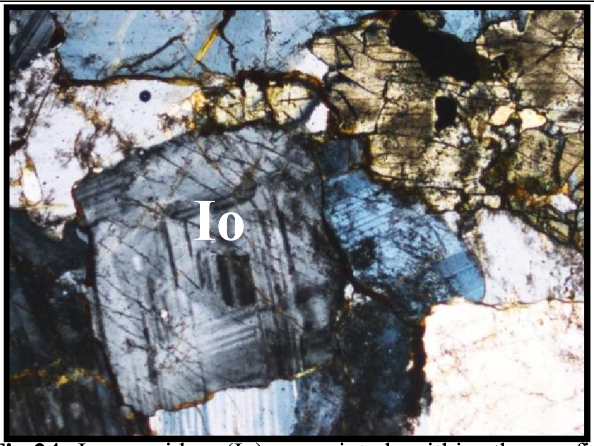


Fig.24 Iron oxides (Io) associated within the mafic minerals (ophitic texure), in the gabbro (C.N.100X).

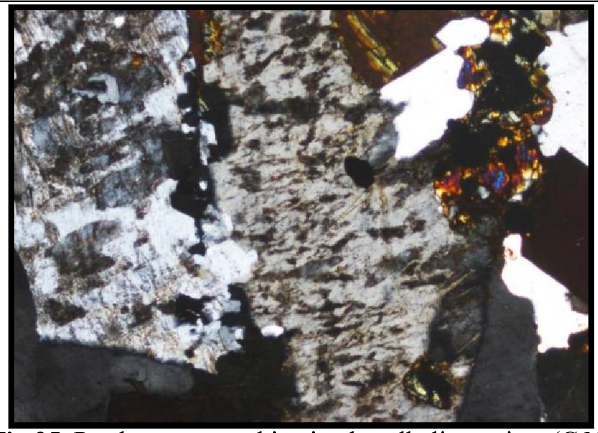


Fig.25 Patchy type perthite in the alkali granite, (C.N. 40X).

Geochemistry and tectonic setting

Actually 31 samples have been analyzed for major and trace elements, 4samples from metavolcanics, 8samples tonalite and graniodiorite, 3samples from monzogranit,3 samples from rhyolite porphyry, 3 samples from gabbro, 5 samples from alkali granite and 5 samples from syenites and quartz syenites).

Early orogenic stage (Island are assemblage)

The investigated samples of the metavolcanics are plotted on Winchester and Floyed, (1977), Cox et. al., (1979) and Le Maitre, (1989) classifications to indicate that they have basalt and andesite composition, (Fig. 26).

Actually, they are related to calc-alkaline and thiolite magma as shown in AFM diagram (Fig.27) of Irvine and Baragar, (1971).

Tectonically the investigated metavolcanics suggest island arc tholeiitic (IAT) and calc-alkaline basalt (CAB) magma as conferred from Mullen (1983) ternary diagram, (Fig.28). However, they are related to arc lava, (Fig.29) according to pearce diagram, (1980). Moreover, they are related to Island arc tholeiitic to calc alkaline magma, (Fig.30) as shown on Floyed diagram, (1991).

Syn to late orogenic stage (continental arc assemblage)

The investigated samples of syn. to late orogenic stage are plotted on middlemost classification, (1985) to confirm that they are composed of tonalite, granodiorite and monzogranite (Fig.31). Generally, the investigated tonalite, graniodiorite and monzogranite samples show sub-alkaline or calc-alkaline affinity as indicated from Irvine and Baragar (1971) diagrams, (Fig.32) and Mac Donald and Bailydiagram (1973). However, they can be considered as meta-luminous rocks according to Maniar and Piccolidiagram (Fig.33), (1989).

Tectonically, the investigated tonalite, granodiorite and monzogranite are related to continental are granites (CAG) according to Maniar and Picolli (1989) diagram (Fig.34), Or volcanic are granites (VAC) according to Pearce et al., (1989) diagram (Fig.35) and ACF diagram (Fig.36) of Takahashi et al., (1980).

According to the trace elements spiderdiagrams normalized relative to the primitive mantle, they display a spicked pattern like as magmatic rocks of an active continental margin, which show considerable decreasing from Rb to Ba and Sr, followed by an increasing of Sr and Zr, (Fig.37), probably suggest a participation of the lower crust, coinciding well with Abu El-Leil et al., (1995,2002,2015).

Post orogenic stage (Rifting).

Four rocks units are related to this stage, forming the ring complex of Gabal Elba. These are rhyolite porphyry, gabbro, alkaline granite and syenites-quartz syenites. The plotted samples of the rhyolite porphyry on Winchester and Floyed (1979) and cox et al., (1979) classifications, show rhyolite composition, (Fig.38. & Fig.39). On the other hand, the gabbro samples are plotted on gabbro field, (Fig.40) according to Cox et al (1979). However, the alkali granite, syenite and quartz syenites are plotted on the field of feldspar syenites, alkali feldspar quartz syenites and alkali granite, (Fig.41) according to Middlemost diagram, (1985). On the other hand, the rhyolite porphyry is moderately alkali rich according to al - alk. diagram (Fig.42), sub - alkaline to partly alkaline (Fig.43) according to Irvine and Baragardiagram (1971).

Moreover, the gabbro has tholeiitic to calc-alkaline affinity and metaluminous character (Fig.44 & Fig.45 & Fig.46) according to Winchester and Floyed (1976) and Irvine and Baragar, (1971) and Maniar and Picolli, (1989) classifications. The chemical affinities of alkali granite, syenites and quartz syenites are varying from relatively alkali-rich to peralkaline, (Fig.47) according to Burri and Nigglidiagram (1985), (Fig.48) or sub-alkaline to alkaline affinity, (Fig.49) according to Irvine Baragar classification, (1971).

Tectonically the investigated rhyolite porphyry, gabbro, alkali granite, syenites, and quartz syenite of Gabal Elba ring complex had been emplaced within the continental plate as shown from the plotted samples on Pearce et al. diagram, (1984) and Maniar and Piccolidiagram, (1989) (Fig.50 & Fig.51). Actually the above mentioned results, precisely recommend bimodal magma, that was responsible of forming Elba ring complex, represented by tholeiitic and alkaline magma. The tholeiitic magma was responsible for forming gabbro, whereas alkaline magma was responsible for forming other rock units.

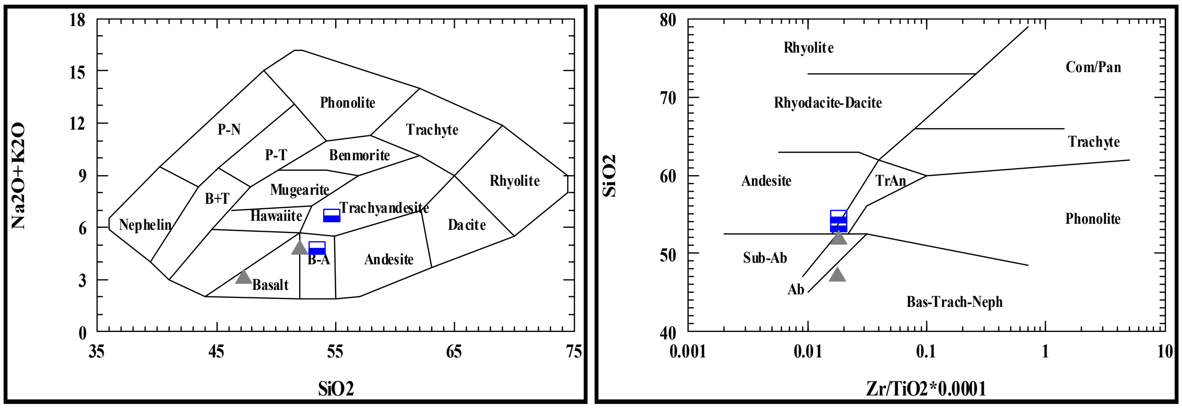
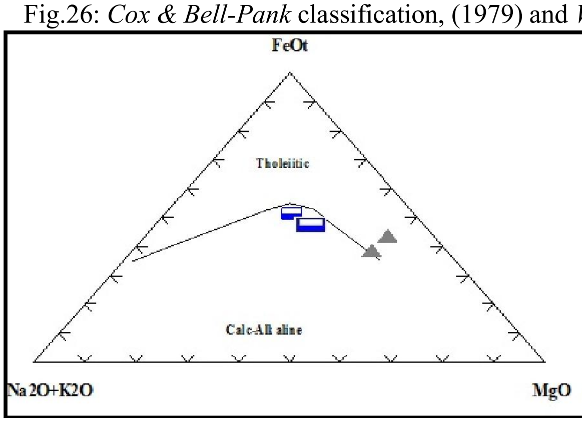


Fig.26: *Cox & Bell-Pank* classification, (1979) and *Winchester and Floyed* classification, (1977).



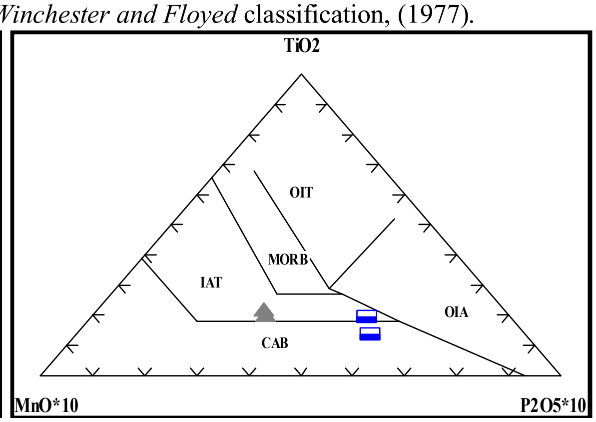
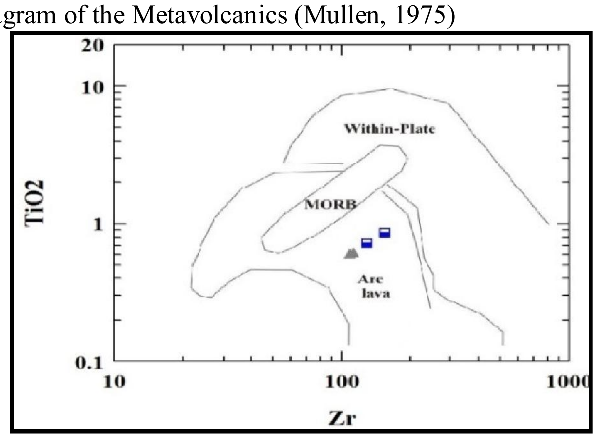


Fig.27: AFM diagram of the Metavolcanics (Irvine and Bararar, (1971).Fig.28: TiO2 – MnO*10 – P2O5 ternary diagram of the Metavolcanics (Mullen, 1975)



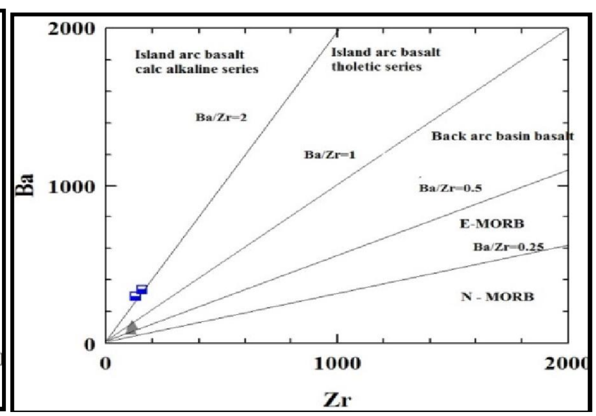
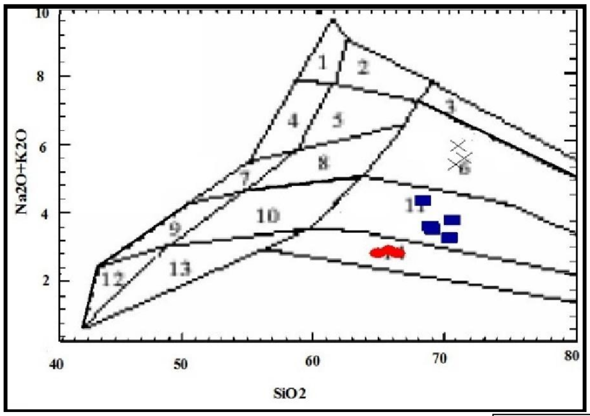
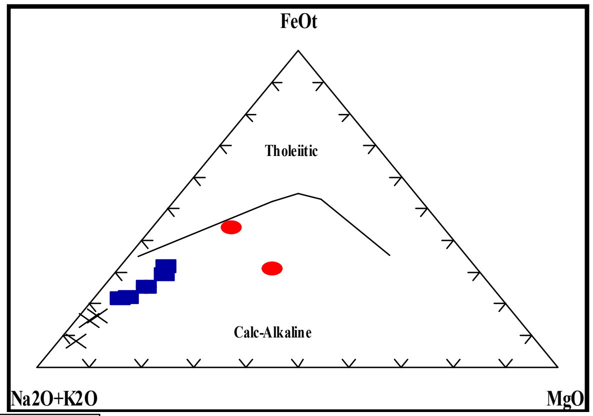


Fig.29: TiO2-Zr diagram of Pearce (1980). Fig.30: Zr vs. Ba diagram of Floyed (1991).

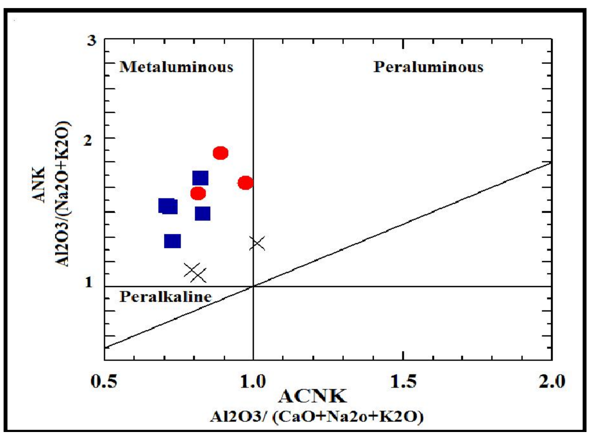
▲Metabasalt ▬Metaandesite





Tonalite
Granodiorite
Monzogranite

Fig.31: Middlemost classification (1985). Fig.32: AFM diagram of syn to late orogenic rocks.



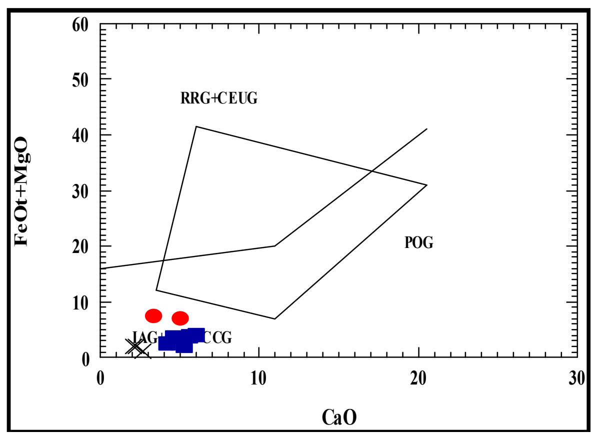
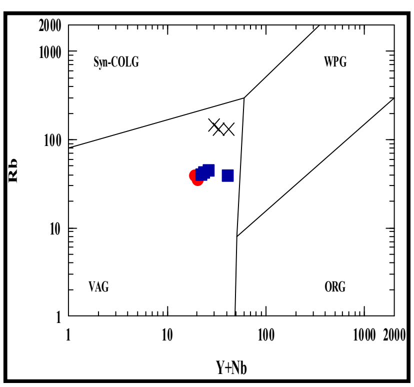
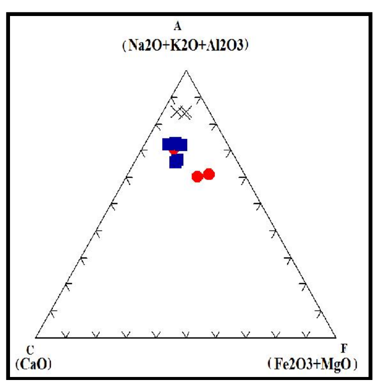


Fig.33: Maniar and Piccoli (1989). Fig.34: Maniar and Piccoli (1989).





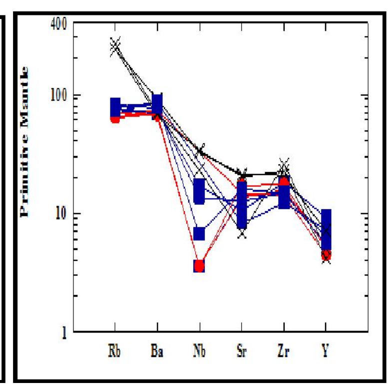
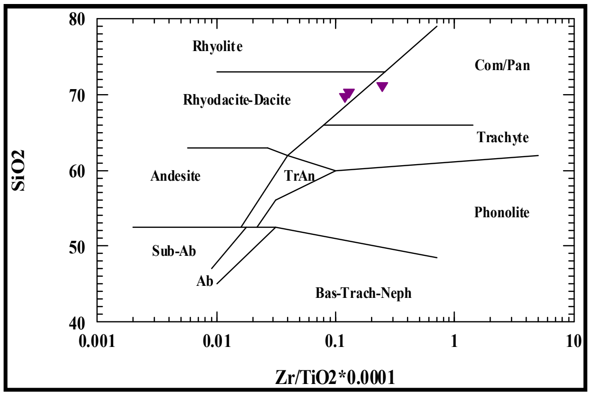


Fig.35: Pearce et al. (1984). Fig.36: Takahashi et.al. (1980). Fig.37: Spiderdiagram, (Wood et al; 1979).



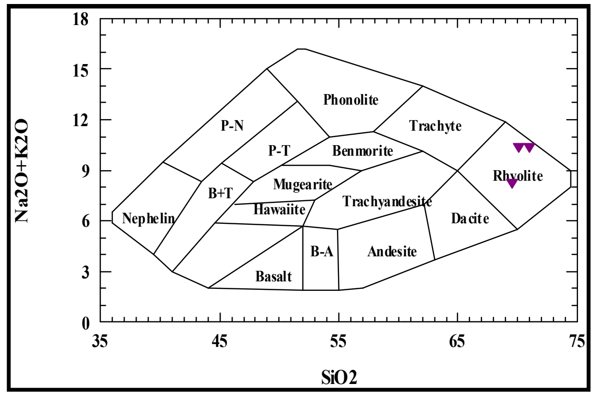
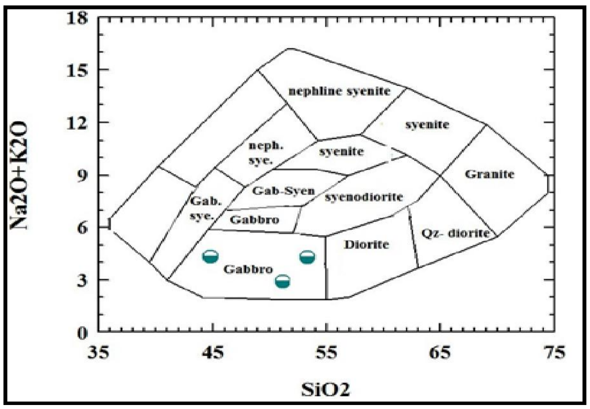


Fig.38: Winchester and Floyed classification, (1977). Fig.39: Cox & Bell-Pank classification, (1979).



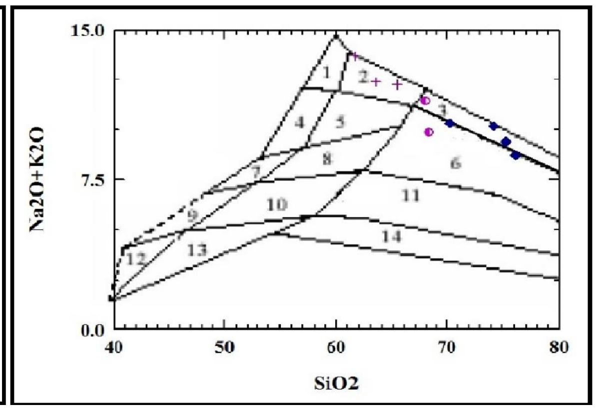
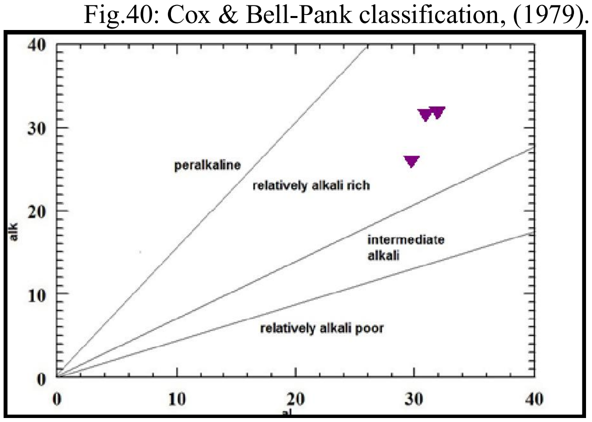


Fig.40: Cox & Bell-Pank classification, (1979). Fig.41: Middlemostclassification (1985).



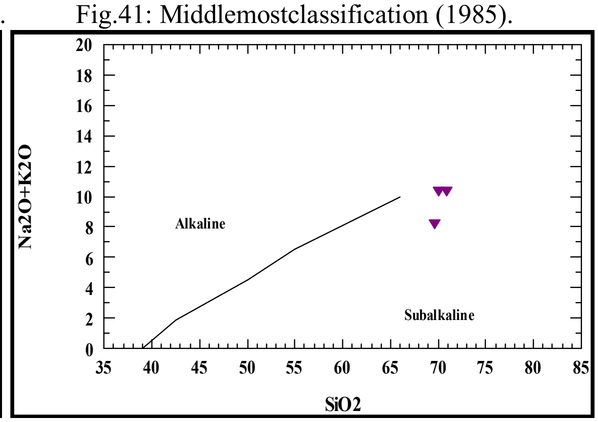
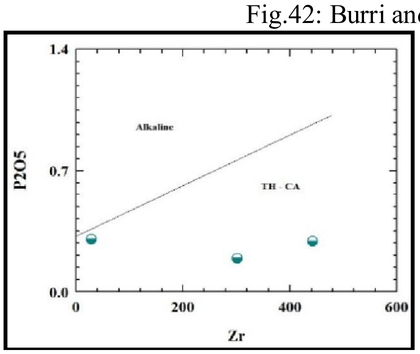
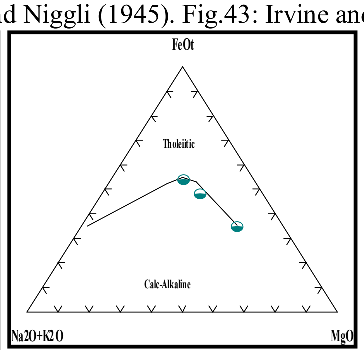


Fig.42: Burri and Niggli (1945). Fig.43: Irvine and Bararar, 1971.





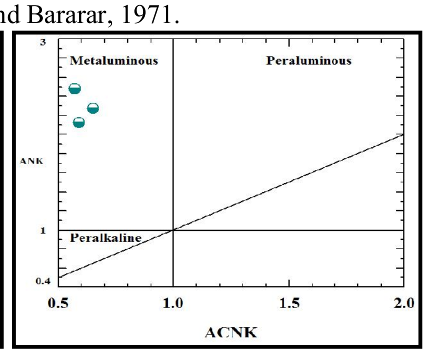


Fig.44: Winchester and Floyed 1976. Fig.45: Irvine and Baragar, (1971). Fig.46: Maniar and Piccoli diagram, (1989).

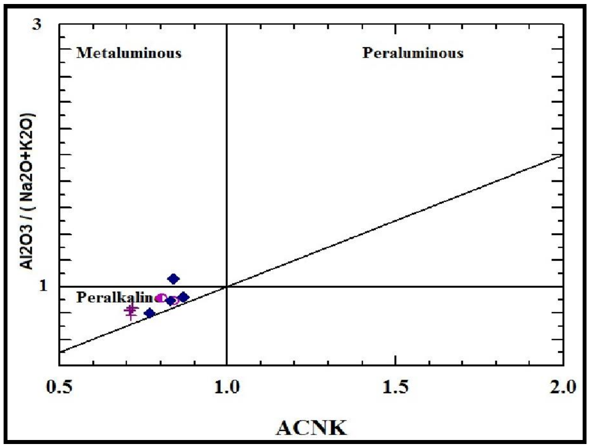


Fig.47: Maniar and Piccoli (1989).

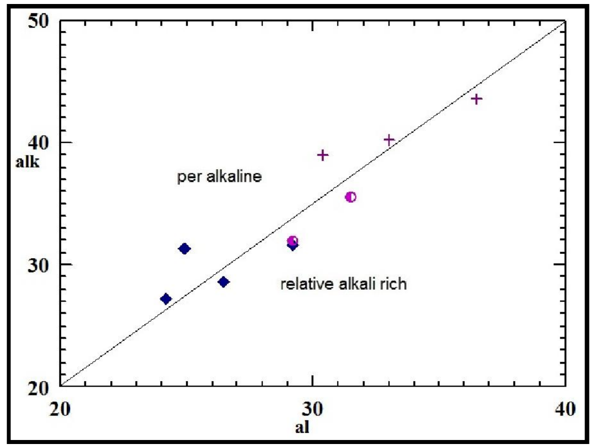


Fig.48: Burri and Niggli (1945).

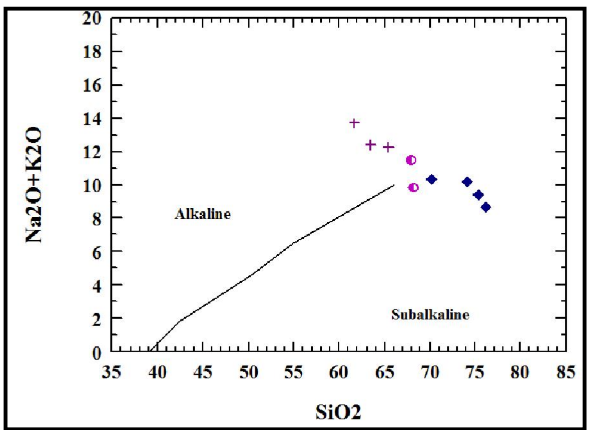


Fig.49: Burri and Niggli (1945).

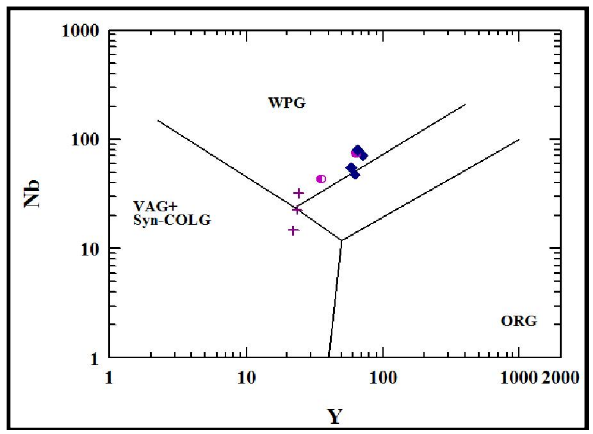


Fig.50: Pearce et al. (1984).

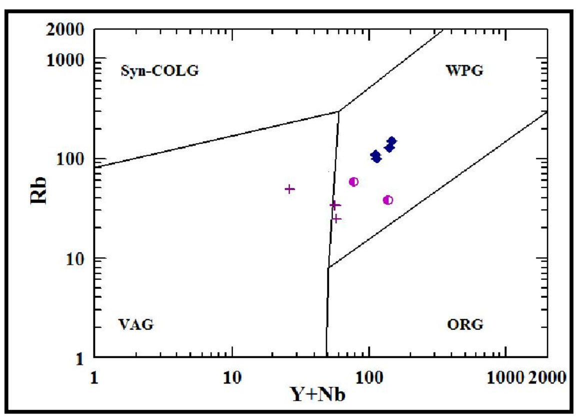


Fig.51: Pearce et al., (1984).

Conclusion

Geological, petro graphical and geochemical studies of Gabal Elba area confirm three tectonic stages, that had been responsible for developing the investigated rock units.

(1) The early orogenic stage was responsible for the metabasalt and metaandesite of metavolcanies.

(2) The syn. to late orogenic stage was responsible for developing the tonalite, granodiorite and monzogranite.

(3) The post orogenic stage was responsible for developing the rhyolite porphyry, gabbro, alkali granite, syenites and quartz syenites of Elba ring complex.

On the other hand the geochemical behavior suggests (1) tholeiitic affinity of the metavolcanics, (2) calc-alkaline affinity of the tonalite, granodiorite and monzogranite, (3) tholeiitic affinity of the gabbro and alkaline feldspar of the rhyolite porphyry, alkali granite, syenites and quartz syenites to suggest bimodal magma for Elba ring complex.

Magma type and tectonic setting confirm island are regime of the metavolcanics, continental arc regime (I-type granite) of the tonalite, granodiorite and monzogranite and within plate and rifting regime of the rhyolite porphyry, gabbro, alkali granite, syenites and quartz syenites of Elba ring complex.

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8/15/2017