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ORIGINAL ARTICLE

# GEOLOGY AND RADIO-ELEMENT POTENTIALITIES OF SOME SELECTED ACID VOLCANIC ROCKS, CENTRAL EASTERN DESERT, EGYPT

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**Abstract:**

*The silicic Dokhan Volcanic rocks of Gabal Nuqara and Gabal Abu Aqarib occupy an area of the Central Eastern Desert, SSW of Safaga city, Egypt. The silicic volcanics of G. Nuqara crop out in two elongate parallel NW-SE trending belts, and are conformably overlain by the intermediate Dokhan Volcanics. The accumulation of the volcanics in belts is not probably consistent with a central (volcanic neck) eruption. The silicic Dokhan Volcanics of G. Abu Aqarib show explosive eruption products giving rise to thinly banded rhyolitic tuffs at the top of the volcanic sequence. G. Nuqara volcanics include rhyolite porphyry, rhyodacite, dacite and equivalent pyroclastics, and G. Abu Aqarib volcanics are rhyolite porphyry, rhyodacite and equivalent pyroclastics. The Dokhan Volcanic (both of G. Nuqara and G. Abu Aqarib) have calc-alkaline affinity with alkali enrichment. They were erupted in a volcanic arc in an active continental margin tectonic setting. The average eU contents of the silicic volcanic rocks of G. Nuqara and G. Abu Aqarib are 9.4 and 8.5 ppm, respectively. Because of the relatively low average content of uranium, visible U mineralization is absent. Uranium is present as a trace in accessory resistate minerals (e.g apatite and zircon).*

**KEYWORDS:**

Dokhan Volcanics–Nuqara – Abu Aqarib – Radio-elements.

## INTRODUCTION:

Gabal (G.) Nuqara study area occupies a part of the Central Eastern Desert of Egypt that is located 3 km southwest of Safaga city on the Red Sea coast. The study area is bounded by latitudes 26o 44' 50" & 26o 39' 28" and longitudes 33o 56' 00" & 33o 50' 13". The second investigated area is at G. Abu Aqarib, south of G. Nuqara lying between latitudes 26o27'28" & 26o 22' 15" and longitude 33o 50' 21" & 33o 45' 40" (Figure 1). The G. Nuqara and G. Abu Aqarib areas have significant exposures of the Dokhan Volcanics, which include silicic lavas and fragmental volcanics that are deemed to be possible sources for U that may be trapped in the volcanics or dispersed into sediments or natural waters derived from them. The Dokhan Volcanics have been investigated in other parts of the Eastern Desert for their radioelement characteristics. Abdel Gwad (2008) recorded that Statistical analyses of the radioelements measurements show that the rhyodacite-rhyolite, ash tuffs and equigranular biotite granite are the most important radioactive rocks in Gabal Monqul Dokhan voncanics area, North Eastern Desert. Previous work on the Dokhan of the Nugara – Abu Aqarib area is limited. Mohamed (1995) recorded that the upper

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Dokhan Volcanics of G. Nuqara originated from high-K calc-alkaline to alkaline magma in an active continental margin environment, with a crustal thickness ranging from 20 to 30 km. El-Sawey (1998) stated that the succession of G. Abu Aqarib Dokhan Volcanics is composed of basaltic andesite and andesite in the lower part and rhyodacite tuffs with subordinate rhyodacite lava flows in the upper part. The age of silicic Dokhan Volcanics of G. Nuqara has been estimated to be 602 ± 12 Ma (using Rb/Sr method), while age estimates for the mafic (intermediate) Dokhan Volcanics range from 622 to 761 Ma (Dixon, 1979; Stern, 1979 and Stern and Hedge, 1985).

This contribution reports our investigations of the field geological characteristics of the Dokhan Volcanics in the G. Nuqara – G. Aqarib areas, with special reference to the geologic and geochemical factors controlling the U-Th distribution within the silicic volcanics of these areas.

## 2-FIELD GEOLOGY

The Dokhan Volcanics represents the dominant rock unit of the G. Nuqara area (Figure 1.1). The volcanics occupy an area measuring about 95 km2. The Dokhan is distinct from the older arc-related metavolcanics farther to the south, by the high relief, sharp peaks and steep slopes of the Dokhan. The G. Nuqara area is dissected by NE-SW and NW-SE trending swarms of felsic and mafic dykes that individually extend for up to several kilometers along their length. In the nearby G. Abu Aqarib area (Figure1.2) the Dokhan Volcanics cover about 53 km2 and comprise a variety of fine felsic, intermediate and mafic extrusives as well as pyroclastics types. Geomorphologically, the Dokhan Volcanics of the Abu Aqarib area form moderately elevated terrains (Figure 2.1). The felsic volcanics are the predominant lithologies and include rhyolite, rhyodacite and their pyroclastics. The Dokhan Volcanics (both of G. Nuqara and G. Abu Aqarib areas) can be subdivided into two units: an intermediate volcanic sequence and a silicic volcanic sequence.

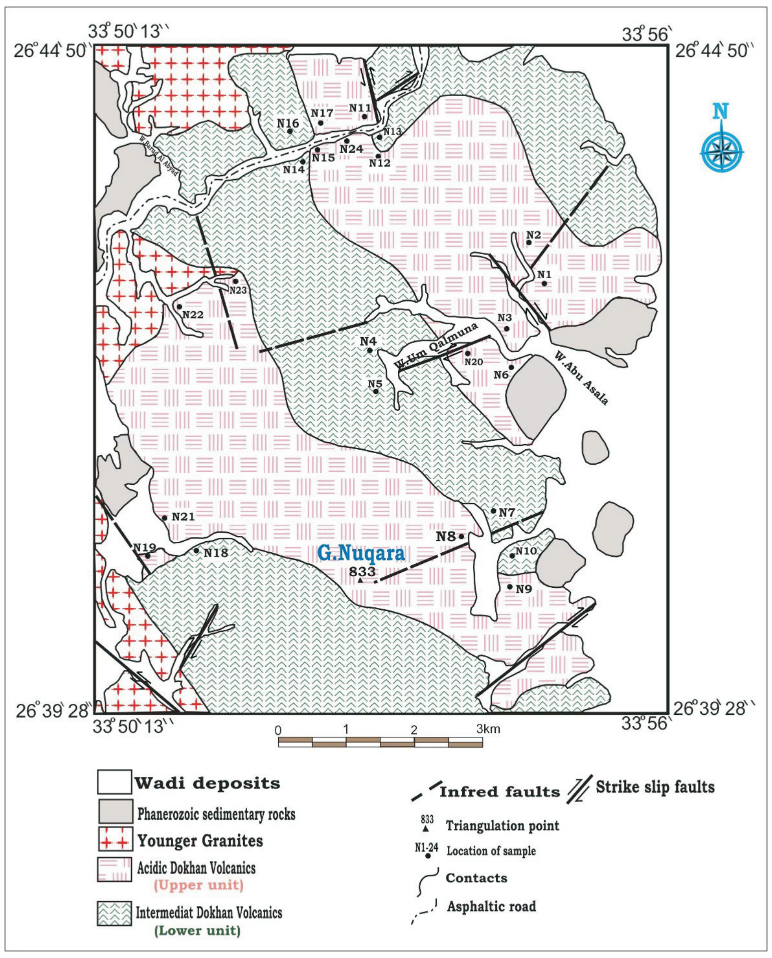


**Figure (1.1) Geologic maps of the studied areas.**

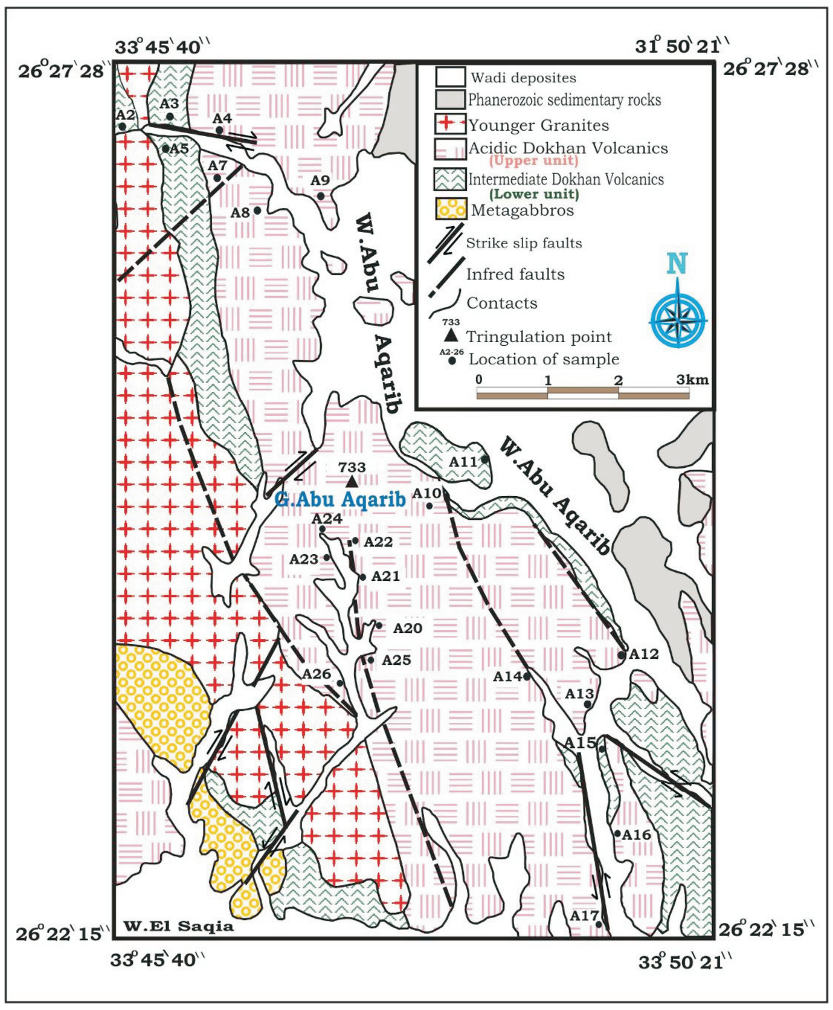


**Figure (1.2): Geologic map of G. Abu Aqarib area.**

The silicic volcanics of G. Nuqara are generally porphyritic and range in colour from brownish red to red. Locally, they show a subtle gradation from porphyritic to non-porphyritic varieties in the same outcrop, suggesting a slow cooling followed by sudden drop of temperature during consolidation. The phenocrysts are mainly feldspars with few quartz crystals and biotite flakes. The non-porphyritic (aphyric) varieties are usually vesicular, suggesting that their parent lava was rich in gases and volatiles (Figure 2.2). The rocks are highly weathered, particularly along their contacts with the lower Dokhan Volcanics.

The pyroclastics are highly compact, hard, massive rocks that vary in colour from light to dark grey and range in grain size from ash to lapilli, and even bombs (Figure 2.3), and contain fragments of varied shapes and sizes (Figure 2.4). They are usually lithic crystal tuffs. The tuffs are mainly rhyodacitic and rhyolitic in composition. The silicic Dokhan Volcanics crop out in the form of two elongated parallel belts trending NW-SE, and are conformably overlain by the intermediate Dokhan Volcanics, which appear as three interposed elongate belts of the same trend.

The upper Dokhan unit of G. Abu Aqarib is generally pink, brownish-red and red in colour, although yellow and yellowish-grey colours are also found. The reddish pigment of these rocks is essentially due to their staining by hematitic granules, which are abundant throughout (Figure 2.5). This unit is essentially composed of pyroclastics (Figure 2.6), and subordinate lava flows.

Pyroclastics are spread over considerable parts of the study area of G. Abu Aqarib and occur as thick beds alternating with the above units. They are represented by rhyodacitic tuffs. The fine-grained tuffs are generally disposed along the peripheral parts giving rise to coarse-grained varieties and lapilli tuffs. They are composed of crystals and crystal fragments of quartz and feldspars. The presence of flow and pyroclastics in such a manner indicates that the volcano or volcanoes from which these volcanic varieties were extruded probably represent a stratovolcano.

## 3-PETROGRAPHIC FEATURES

The silicic Dokhan volcanics of Gabal Nuqara are classified petrographically as rhyolite, dacite, rhyodacite, and pyroclastics, while the silicic Dokhan volcanics of Gabal Abu Aqarib are classified as rhyolite porphyry, rhyodacite and pyroclastics.

### 3.1 Silicic Dokhan Volcanics of G. Nuqara

Rhyolites consist of phenocrysts of alkali feldspars (sanidine and string-type orthoclase perthites) and quartz embedded in a microcrystalline felsic groundmass. Alkali feldspars are represented by generally subhedral crystals showing simple twinning (Figure 3.1 ) while quartz phenocrysts are sometimes fractured and highly embayed by the groundmass and show amoeboid shapes (Figure 3.2). Dacites are porphyritic with characteristic graphic texture (Figure 3.3). There are no amygdaloidal varieties. The phenocrysts in the dacites are mainly plagioclase with few embayed quartz and sanidine crystals. Altered crystals are very rare in the dacites compared with the rhyolite porphyry, but along microfault planes the crystals become highly altered and cracked. Rhyodacites resemble porphyritic dacites, but they contain more sanidine crystals and more sodic plagioclase, and there is no hornblende in the rhyodacites. The groundmass consists of slender plagioclase laths with interstices filled with carbonate and iron oxides (Figure 3.4). Graphic texture is present as a result of the intergrowth between quartz and feldspars.

### 3.2. Pyroclastics

Lapilli tuffs are the most common pyroclastics. They occur in three forms: crystal tuffs, lithic tuffs (Figure 3.5) and crystal lithic tuffs. They sometimes show laminated and welded textures (Fig. 23). The crystal fragments are mainly of quartz and plagioclase (Figure 3.6), and alkali feldspar crystals are less common.

### 3.3. Silicic Dokhan Volcanics of G. Abu Aqarib

Rhyolites are characterized by a conspicuous porphyritic texture and myrmekitic texture (Figure 3.7) produced by intergrowth of quartz and plagioclase, in which the quartz occurs as drops or vermicular shaped grains within the feldspars, suggesting low rate of cooling. Microscopically, they are composed principally of phenocrysts of sanidine (Figure 3.8&3.9) and quartz together with minor amount of plagioclase, set in a fine-grained groundmass of spherulitic texture. Iron oxide, sulphide, and apatite (3.10) are minor accessories. Rhyodacite is a fine-grained rock characterized by porphyritic textures. It consists of quartz (Figure3.11), sanidine and plagioclase as major constituents embedded in a cryptocrystalline groundmass. Iron oxide, apatite and sulfide are the main accessories.

### 3.4. Pyroclastics

This rock is represented mainly by rhyodacitic crystal tuffs which are composed essentially of plagioclase (Figure 3.12), quartz, and minor amounts of sanidine. The matrix is very fine-grained and consists of plagioclase, quartz and sanidine.

Figure (2.1): G. Nuqara Dokhan volcanics showing high to moderate relief, sharp peaks and steep slopes, looking southeast.

Figure (2.2): Close up view showing **silicic** Dokhan Volcanics with aracteristic vesicular surfaces.

Figure (2.3): General view Looking west showing pyroclastics, bombs and brecciated clastics in the lower Dokhan Volcanics.

Figure (2.4): Close up view of Fractured tuffs showing kinked lamination.

Figure (2.5): Close up view showing hematized zone of silicic Dokhan Volcanics enclosing quartz bodies.

Figure (2.6): Close-up view of silicic pyroclastics including irregular shaped rock fragments of different types

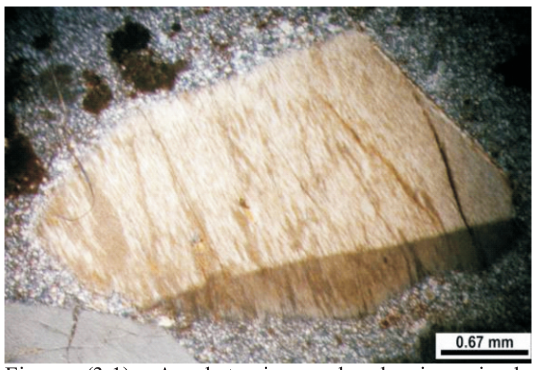


Figure (3.1): A photomicrograph showing simply twinned sanidine, 5x C.N.

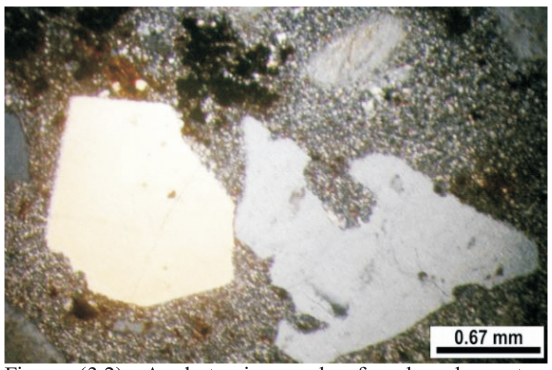


Figure (3.2): A photomicrograph of embayed quartz showing amoeboid shape. 5xC.N.

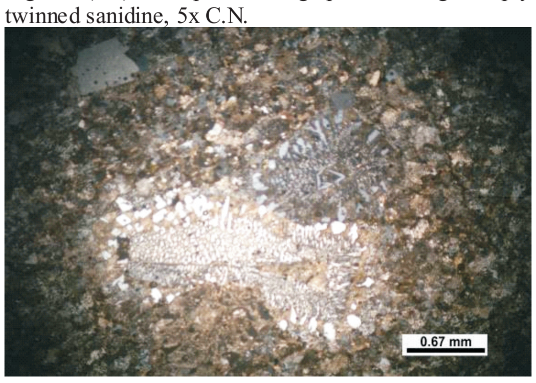


Figure (3.9): A photomicrograph showing graphic texture in dacite. 5x C.N.


Figure (3.10): A photomicrograph showing iron oxide coating quartz and feldspar and corroded them in Rhyodacite, 10x P.L.

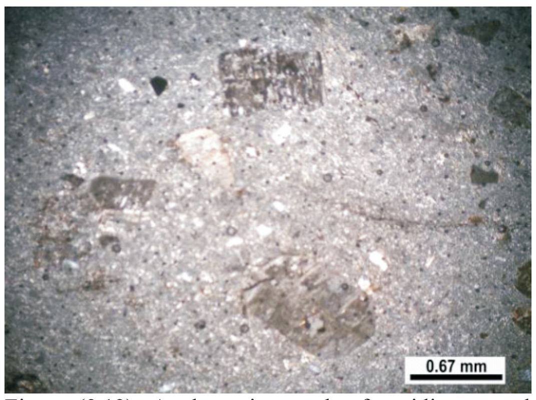


Figure (3.13): A photomicrograph of sanidine crystal fragment in silicic lithic crystal tuffus, 5x C.N.

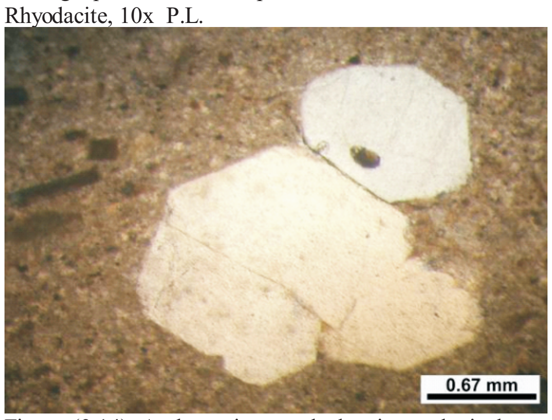


Figure (3.14): A photomicrograph showing plagioclase corroded with ground mass in dacitic welded tuff, 5x C.N.

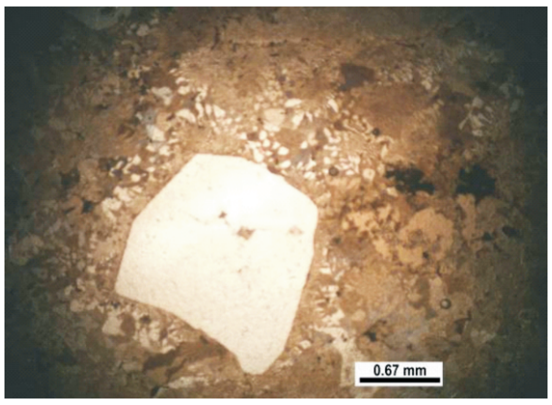


Figure (3.7): A photomicrograph of quartz showing myrmiekitic texture with alkali feldspar in rhyolite, 5x C.N.

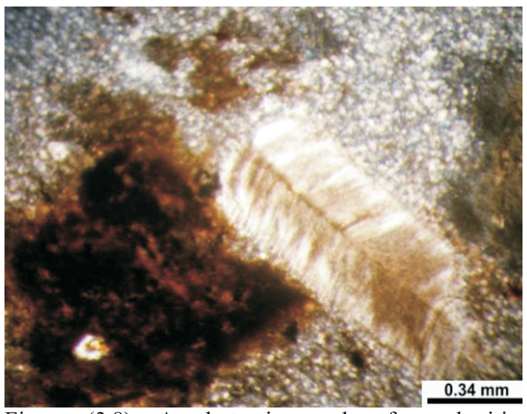


Figure (3.8): A photomicrograph of porphyritic ,holocrystaline simply twined sanidine pheynocryst in rhyolite, 10x C.N.

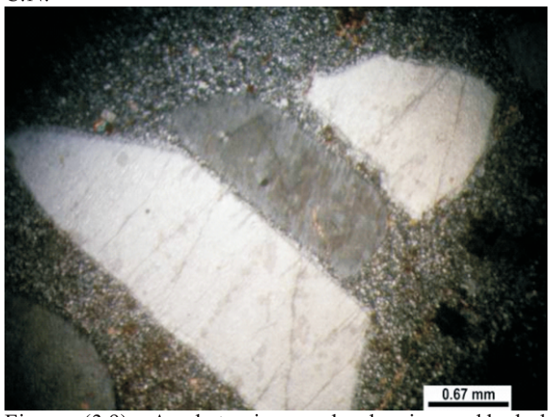


Figure (3.9): A photomicrograph showing subhedral sanidine crystals slightly cracked in rhyolite, 5x C.N.

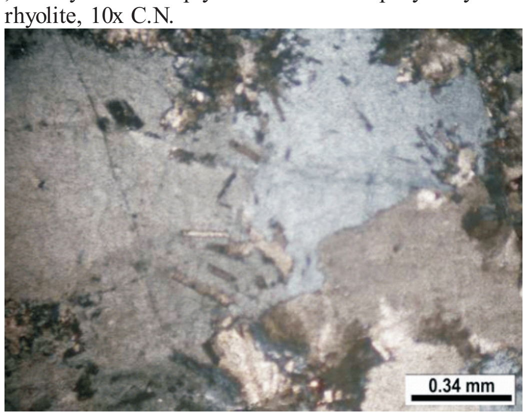


Figure (3.10): A photomicrograph showing several apatite crystals enclosed in quartz, Rhyodacite, 5x C.N.

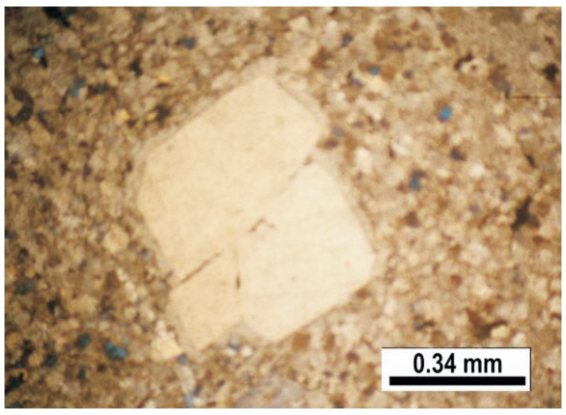


Figure (3.11): A photomicrograph showing cracked quartz phenocryst suggesting high tectonics in Rhyodacite, 5x C.N.

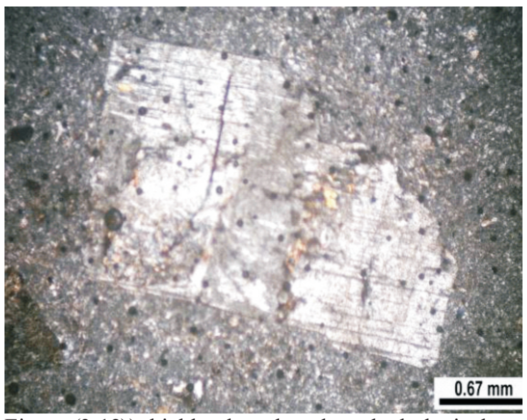


Figure (3.12)): highly altered and cracked plagioclase corroded with groundmass (tuffecous materials), 5x C.N.

## 4-GEOCHEMISTRY

Twenty eight samples were chemically analysed, (13 samples from G. Nuqara and 15 samples from G. Abu Aqarib). These samples were chemically analysed for major oxides and trace elements by means of wet chemical techniques (Shapiro and Brannock, 1962) and X-ray fluorescence (Phillips PW 1410 together with a MO-target at 50 kv and 30 m A) for trace elements.

The differentiation index (D.I.) is a measure of the leucocratic nature of igneous rocks (Thornton and Tuttle, 1960). In the studied areas, the differentiation index (D.I.) values of the studied silicic Dokhan Volcanics of G. Nuqara are of very wide range (from 87.28 to 93.5), which increase gradually from samples have low content of silica to rhyolites that have a high content of silica (Table 1). Dacites of G. Nuqara have (D.I.) of average value 88.88. The rhyodacites have average (D.I) value of 90.12 while the rhyolites have (D.I) of 92.61 on average. The differentiation index (D.I.) values of the studied silicic Dokhan Volcanics of G. Abu Aqarib also have very wide range (from 89.66 to 95.47), which increases gradually from samples have low content of silica to rhyolites, which have high content of silica (Table 2). Rhyodacites have average (D.I) value of 90.8, while rhyolites have average (D.I) value of 93.54. Within each rock type the (D.I.) values show a very narrow range reflecting a high degree of homogeneity.

### 4.1. Classification, magma type and tectonic setting

Classification of the studied volcanic rocks was attempted using the diagrams of Winchester & Floyd (1977). Accordingly, these volcanics can be classified as rhyolite, rhyodacite and dacite in G. Nuqara, while the silicic volcanics of G. Abu Aqarib are rhyolite and rhyodacite (Figure 4.1). Furthermore, the volcanic rocks are plotted on the $K_2O$- $SiO_2$ variation diagram given by Peccerillo and Taylor (1976) to illustrate potassic nature. It is evident that the studied rocks exhibit high potassic affinity (Figure 4.2).

Applying the total alkali-silica variation diagram (Irvine and Baragar, 1971) to discriminate between the alkaline and subalkaline volcanics, the studied volcanic rocks plot in the subalkaline field (Figure 4.3), indicating orogenic tectonic setting. The subalkaline volcanics can be subdivided into calc-alkaline and tholeiitic rocks (Irvine and Baragar, 1971), using the standard A-F-M ternary diagram. The Nb versus $SiO_2$ (wt%) diagram was proposed by Pearce and Gale (1977) ) to discriminate between volcanic arc (low Nb) and within-plate (high Nb) rocks as in (Figure 5.3a). The studied Dokhan Volcanic rocks fall mainly within volcanic arc magma (Figure 4.5). On the $TiO_2$ – $SiO_2$ variation diagram after Ewart, 1982 (Figure 4.6), the studied Dokhan Volcanic rocks plot in the field of immature island arc and active continental margin.

### 4.2. Distribution of eU and eTh

In this work, a calibrated portable gamma-ray spectrometer (model GS-256) was used to measure the gamma-rays emitted from the daughter products of U and Th. The average eU content of the silicic volcanic rocks of G.Nuqara and the silicic volcanic rocks of G. Abu Aqarib are 9.4 and 8.5 ppm, respectively, while their average eTh contents are 23.1 and 19, respectively.

In highly weathered and jointed zones, both of the acidic volcanic rocks in G. Nuqara and G. Abu Aqarib show eU contents less than 3 ppm. Along the alteration zones, the acidic volcanic rocks at G. Nuqara show high eU contents rising to 19.3 ppm, while the acidic volcanic rocks at G. Abu Aqarib show high eU contents reaching 20.7 ppm. The silicic volcanic rocks in G. Abu Aqarib attain their maximum eU value (33.1 ppm) at their contact with the intermediate volcanic rocks, while the acidic volcanic rocks reach 18.4 ppm in G. Nuqara. The minimum values of eU in the acidic volcanics of G.Nuqara and G. Abu Aqarib are 2.4 and 0.8, respectively.

Normally, thorium is three times as abundant as uranium in rocks. When this ratio is disturbed, it indicates depletion (leaching) or enrichment (addition) of uranium. In this work, silicic volcanic rocks at G. Nuqara and G. Abu Aqarib showed average eTh/eU ratio of 0.42 and 0.55 respectively (less than 3), suggesting addition. This may indicate a post-magmatic origin for the uranium. During these secondary processes, the uranium was leached from highly altered and tectonized pre-existing rocks as well as the intermediate Dokhan volcanics themselves, and was redeposited in microfractures in the silicic volcanics, especially in the ferruginated zones. This may be due to the high ability of iron oxides to adsorb uranium from solution (Hussein et al., 1965), or due to the prevalence of oxidation conditions and complexing ions, that cause the precipitation of uranium as complex uranyl ions (Cuney, 2003).

**Table (1): Chemical analysis of major oxides and trace elements of the studied acidic Dokhan volcanics of G. Nuqara.**

| Rock type | Rhyolite | | | | Rhyodacite | | | | | | Dacite | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Symbol | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Sample No. | N1 | N8 | N9 | N6 | N12 | N15 | N17 | N21 | N23 | N24 | N11 | N20 | N22 |
| $SiO_2$ | 74.8 | 74.7 | 74.2 | 72.9 | 71 | 71.4 | 72.1 | 71.6 | 70.3 | 71 | 69.7 | 70 | 69 |
| $TiO_2$ | 0.2 | 0.24 | 0.23 | 0.3 | 0.32 | 0.27 | 0.3 | 0.33 | 0.39 | 0.33 | 0.3 | 0.32 | 0.32 |
| $Al_3O_3$ | 13.3 | 13.2 | 13.4 | 13.5 | 16.3 | 16.6 | 15 | 14.64 | 14.4 | 15.6 | 16.03 | 15.65 | 15.5 |
| $Fe_2O_3$ | 2.4 | 2.1 | 2.2 | 2.9 | 3.03 | 2.07 | 2.7 | 4.2 | 3.3 | 2.2 | 3.5 | 3.5 | 3.7 |
| MgO | 0.4 | 0.36 | 0.36 | 0.21 | 0.1 | 0.12 | 0.2 | 0.4 | 0.47 | 0.5 | 0.1 | 0.1 | 0.2 |
| CaO | 0.5 | 0.45 | 0.45 | 0.6 | 0.51 | 0.314 | 0.5 | 0.22 | 0.39 | 0.8 | 1.18 | 0.2 | 1.12 |
| $Na_2O$ | 3.4 | 3.9 | 3.66 | 4.16 | 3.2 | 3.9 | 4.07 | 3.6 | 3.7 | 4.12 | 3.9 | 4.12 | 4.12 |
| $K_2O$ | 4.3 | 4.52 | 4.25 | 4.64 | 4.31 | 4.35 | 4.6 | 4.12 | 4.7 | 4.5 | 4.38 | 4.7 | 5.04 |
| $P_2O_5$ | 0.003 | 0.04 | 0.06 | 0.02 | 0.005 | 0.001 | 0.001 | 0.06 | 0.17 | 0.007 | 0.01 | 0.7 | 0.002 |
| $H_2O^+$ | 0.08 | 0.46 | 1.13 | 0.64 | 0.6 | 0.7 | 0.5 | 0.6 | 1.3 | 0.8 | 0.6 | 0.7 | 0.9 |
| Total | 99.383 | 99.96 | 99.94 | 99.87 | 99.37 | 99.72 | 99.971 | 99.77 | 99.12 | 99.857 | 99.7 | 99.99 | 99.91 |
| D.I | 91.74 | 93.5 | 92.49 | 92.74 | 88.3 | 90.82 | 90.93 | 88.64 | 92.29 | 89.78 | 87.28 | 90.77 | 88.59 |
| $K_2O/Na_2O$ | 1.26 | 1.15 | 1.16 | 1.11 | 1.34 | 1.11 | 1.13 | 1.14 | 1.27 | 1.09 | 1.12 | 1.14 | 1.22 |
| Some of trace elements (ppm) | | | | | | | | | | | | | |
| Ba | 520 | 460 | 397 | 507 | 432 | 432 | 389 | 407 | 645 | 465 | 473 | 505 | 452 |
| Y | 48 | 51 | 38 | 44 | 52 | 42 | 41 | 49 | 44 | 45 | 49 | 41 | 47 |
| V | 5 | 3 | 4 | 3 | 4 | 4 | 5 | 4 | 11 | u.d | 4 | u.d | 5 |
| Rb | 79 | 105 | 158 | 127 | 131 | 114 | 117 | 167 | 52 | 154 | 143 | 174 | 95 |
| Zr | 312 | 293 | 217 | 301 | 220 | 206 | 235 | 269 | 231 | 207 | 249 | 192 | 304 |
| Cr | 21 | 26 | 30 | 20 | 21 | 23 | 19 | 23 | 16 | 24 | 28 | 29 | 19 |
| Sr | 35 | 24 | 33 | 33 | 33 | 21 | 95 | 36 | 130 | 41 | 25 | 42 | 39 |
| Nb | 14 | 16 | 19 | 14 | 11 | 17 | 17 | 26 | 12 | 15 | 13 | 21 | 17 |
| Ni | 8 | 8 | 7 | 7 | 9 | 7 | 6 | 8 | 7 | 7 | 7 | 7 | 7 |

**D.I (Differentiation Index)** **u.d (under detected)** + **Acidic Dokhan Volcanic of G. Nuqara**

**Table (2): Chemical analysis of major oxides and trace elements of the studied acidic Dokhan volcanics of G. Abu Aqarib.**

| Rock type | Rhyolite | | | | | | | | | | | | Rhyodacite | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Symbol | ◇ | ◇ | ◇ | ◇ | ◇ | ◇ | ◇ | ◇ | ◇ | ◇ | ◇ | ◇ | ◇ | ◇ | ◇ |
| Sample No. | A10 | A12 | A14 | A20 | A21 | A23 | A25 | A26 | A4 | A7 | A8 | A9 | A16 | A17 | A13 |
| $SiO_2$ | 74.2 | 73.4 | 74.8 | 73.15 | 74.56 | 74.2 | 73.8 | 74.7 | 73.5 | 74 | 74.54 | 73.6 | 71 | 70.2 | 72.1 |
| $TiO_2$ | 0.17 | 0.18 | 0.2 | 0.13 | 0.21 | 0.23 | 0.16 | 0.23 | 0.18 | 0.17 | 0.19 | 0.18 | 0.34 | 0.33 | 0.3 |
| $Al_3O_3$ | 13.6 | 13.5 | 13.3 | 14.2 | 13.3 | 13.4 | 13.8 | 13.2 | 13.5 | 13.5 | 13.5 | 13.2 | 15.6 | 15.64 | 15 |
| $Fe_2O_3$ | 1.2 | 1.8 | 2.4 | 1.5 | 1.4 | 2.2 | 1.1 | 2.1 | 1.7 | 2 | 1.9 | 2.5 | 2.2 | 3.5 | 2.7 |
| MgO | 0.36 | 0.3 | 0.4 | 0.12 | 0.28 | 0.36 | 0.64 | 0.36 | 0.4 | 0.2 | 0.3 | 0.3 | 0.5 | 0.1 | 0.2 |
| CaO | 0.5 | 0.5 | 0.5 | 0.9 | 0.45 | 0.45 | 0.45 | 0.45 | 0.8 | 0.5 | 0.4 | 0.6 | 0.8 | 0.4 | 0.5 |
| $Na_2O$ | 4.2 | 4.04 | 3.4 | 4.36 | 4.36 | 3.66 | 4.06 | 3.9 | 4.04 | 4.04 | 4.04 | 4.3 | 4.11 | 4.12 | 4.07 |
| $K_2O$ | 4.9 | 4.8 | 4.3 | 4.8 | 4.5 | 4.25 | 4.41 | 4.52 | 4.7 | 4.5 | 4.3 | 4.7 | 4.5 | 4.7 | 4.6 |
| $P_2O_5$ | 0.001 | 0.003 | 0.003 | 0.02 | 0.3 | 0.06 | 0.03 | 0.04 | 0.001 | 0.07 | 0.002 | 0.001 | 0.007 | 0.007 | 0.001 |
| $H_2O^+$ | 0.47 | 0.5 | 0.08 | 0.6 | 0.6 | 1.13 | 0.95 | 0.46 | 0.8 | 0.9 | 0.4 | 0.6 | 0.8 | 0.7 | 0.5 |
| Total | 99.61 | 99.023 | 99.383 | 99.78 | 99.96 | 99.94 | 99.4 | 99.96 | 99.621 | 99.88 | 99.572 | 99.981 | 99.857 | 99.697 | 99.971 |
| D.I | 94.75 | 93.98 | 91.72 | 93.4 | 95.47 | 92.49 | 93.33 | 93.51 | 92.76 | 93.83 | 93.67 | 93.66 | 89.66 | 90.81 | 91.95 |
| $K_2O/Na_2O$ | 1.16 | 1.18 | 1.26 | 1.10 | 1.03 | 1.16 | 1.08 | 1.15 | 1.16 | 1.11 | 1.06 | 1.09 | 1.09 | 1.14 | 1.13 |
| Some of trace elements (ppm) | | | | | | | | | | | | | | | |
| Ba | 421 | 456 | 475 | 390 | 358 | 418 | 449 | 400 | 545 | 369 | 469 | 340 | 450 | 520 | 442 |
| Y | 42 | 41 | 45 | 45 | 58 | 39 | 49 | 37 | 41 | 57 | 47 | 33 | 43 | 70 | 38 |
| V | 4 | 3 | 4 | 4 | 4 | 3 | 5 | 3 | 4 | 4 | 5 | 3 | 2 | 4 | 4 |
| Rb | 93 | 87 | 139 | 127 | 100 | 115 | 98 | 81 | 69 | 87 | 91 | 112 | 197 | 56 | 149 |
| Zr | 201 | 303 | 482 | 333 | 323 | 312 | 390 | 392 | 290 | 267 | 357 | 285 | 249 | 328 | 351 |
| Cr | 28 | 23 | 28 | 28 | 26 | 28 | 28 | 28 | 25 | 23 | 30 | 30 | 27 | 24 | 23 |
| Sr | 30 | 45 | 16 | 56 | 63 | 30 | 59 | 45 | 55 | 63 | 67 | 30 | 39 | 48 | 63 |
| Nb | 23 | 17 | 23 | 14 | 21 | 24 | 17 | 28 | 27 | 22 | 24 | 22 | 16 | 27 | 21 |
| Ni | 6 | 7 | 7 | 7 | 8 | 8 | 7 | 7 | 6 | 7 | 8 | 7 | 8 | 7 | 8 |

**D.I (Differentiation Index)** **u.d (under detected)** ◇ **Acidic Dokhan Volcanics of G.Abu Aqarib**

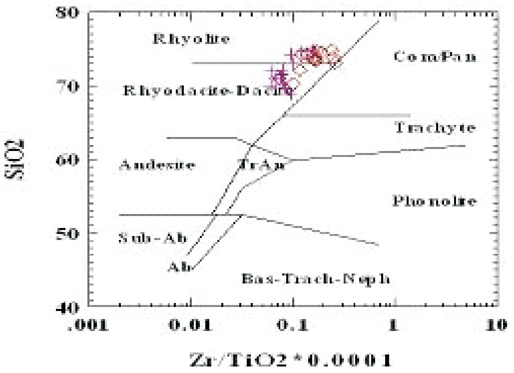


Figure (4.1): $SiO_2$ versus Zr/TiO2 diagram (after Winchester & Floyd, 1977). ) . + silicic Dokhan Volcanic of G. Nuqara, ? silicic Dokhan Volcanics of G.Abu Aqarib.

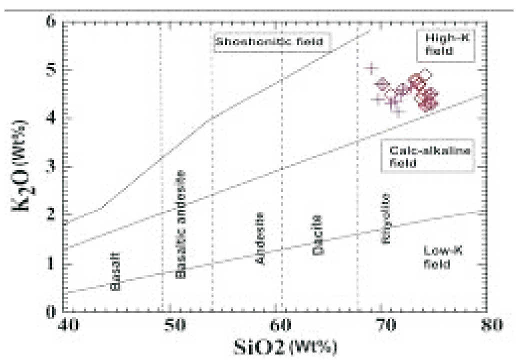


Figure (4.2): K2O versus SiO2 Diagram (after Peccerillo and Taylor, 1976) for the studied Dokhan Volcancs of G.Nuqara and G.Abu Aqarib. Symbols as seen in figure (4.1).

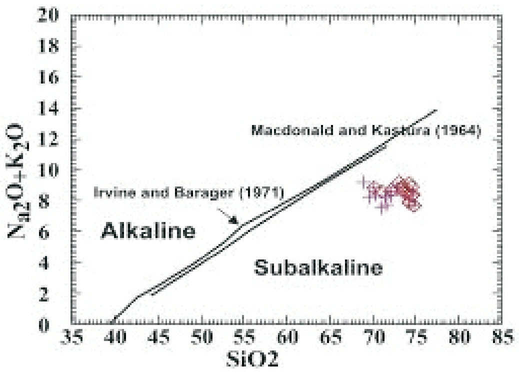


Figure (4.3): Alkali - silica variation diagram, after (Irvine & Baragar, 1971) for the studied silicic Dokhan Volcanics of G. Nuqara and G. Abu Aqarib. Symbols as seen in figure (4.1).

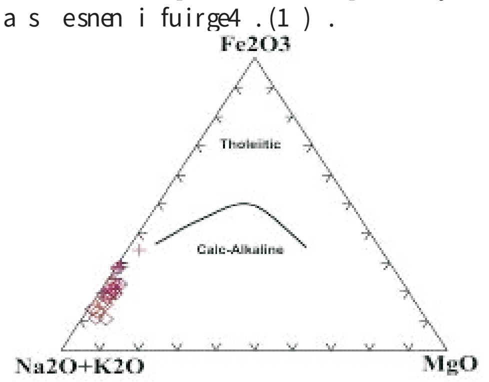


Figure (4.4): AFM diagram after (Irvine & Baragar, 1971) for the studied silicic Dokhan Volcanics of G. Nuqara and G. Abu Aqarib. Symbols as seen in figure (4.1).

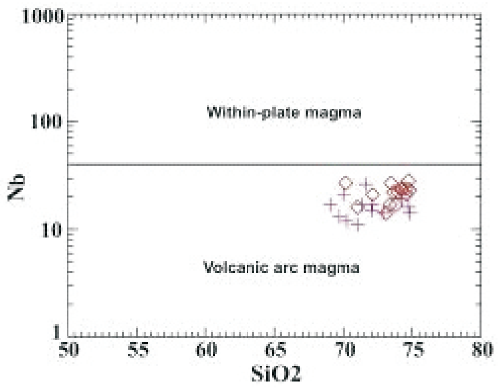


Figure (4.5): Nb – $SiO_2$ diagram after (Pearce & Gale, 1977), for the studied silicic Dokhan Volcanics of G.Nuqara and G.Abu Aqarib. Symbols as seen in figure (4.1)

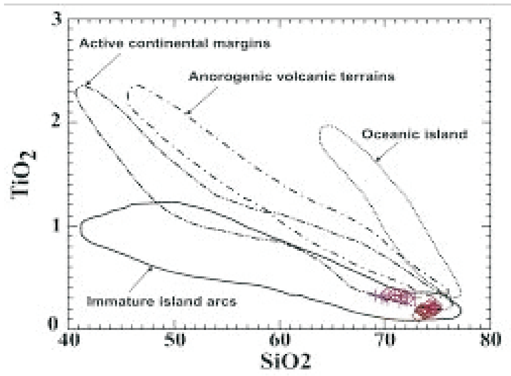


Figure (4.6): $SiO_2$ versus $TiO_2$ variation diagram (Ewart,1982) ), for the studied silicic Dokhan Volcanics of G.Nuqara and G.Abu Aqarib. Symbols as seen in figure (4.1).

The diagram eU versus (eU-eTh/3.5) shows a direct relation in which (eU-eTh/3.5) reflects the uranium mobilization (Figs. 5.4c,d). When this value is equal to zero it signifies that the mobilization of uranium is effectively zero, which indicates that no uranium mobilization (i.e. fresh samples). However, when the surface uranium distribution is greater than zero, the (eU-eTh/3.5) has positive values indicating that uranium was leached in. If the surface uranium distribution is less than zero, the uranium mobilization has negative values, which means that uranium is leached out.

Because of the relatively low average content of uranium, visible minerlaization is absent. Uranium is present as an inclusion in accessory minerals such as apatite and zircon (Figure and tied up in these resistate minerals.

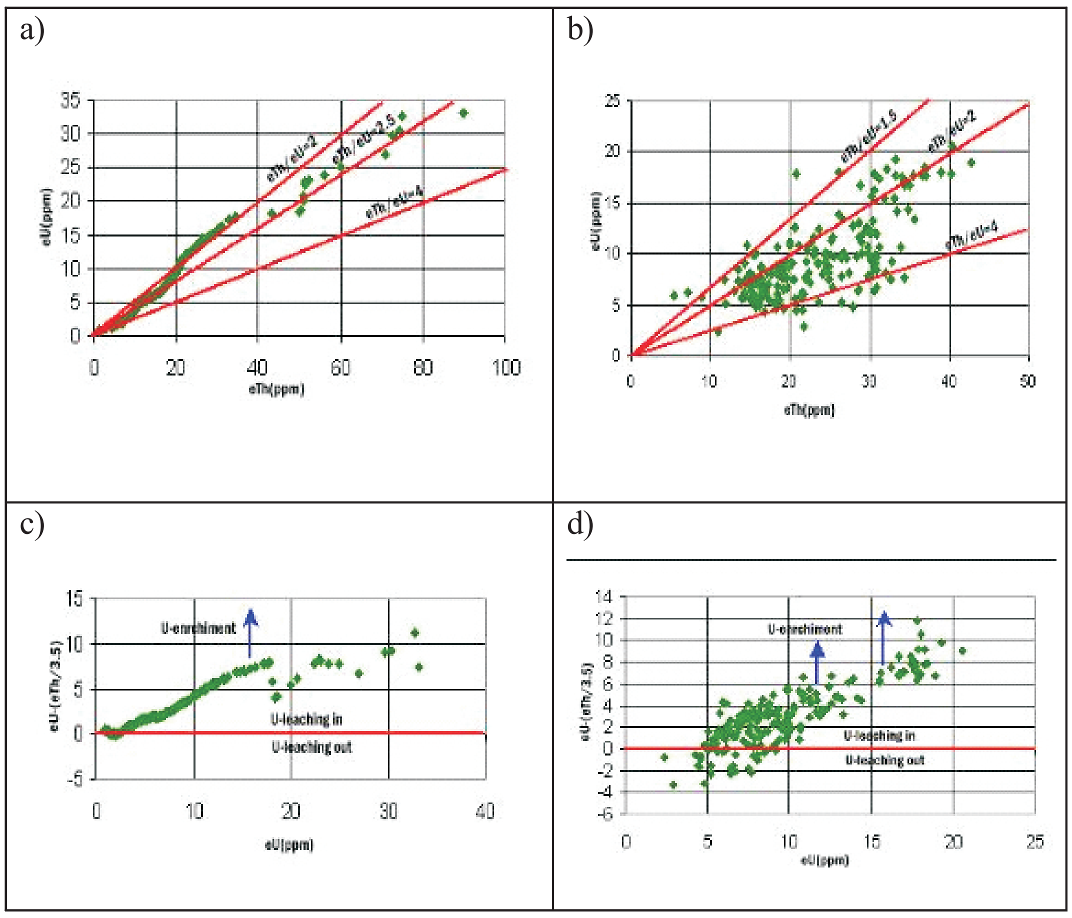


**Figure (5.4): Radioactive element plots for ground-gama-ray spectrometry measurements from silicic volcanics of G. Nuqara and G. Abu Aqarib. Figures (a & c) for G. Nuqara and (b & d) for G. Abu Aqarib**

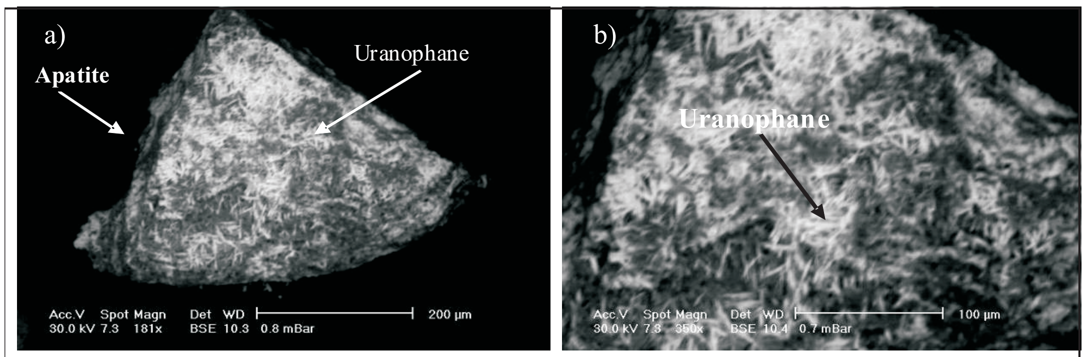


Figure (5.6a &b): Microphotograph by environmental Scanning Electron Microscope (ESEM) for a) apatite with inclusions of uranophane and b) uranophane

c)

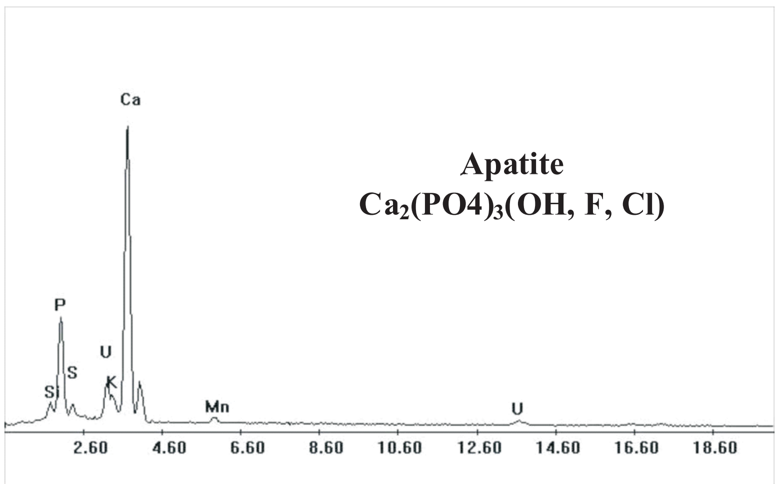


Figure (5.6c): EDAX chart for apatite by Environmental Scanning Electron Microscope (ESEM).

d)

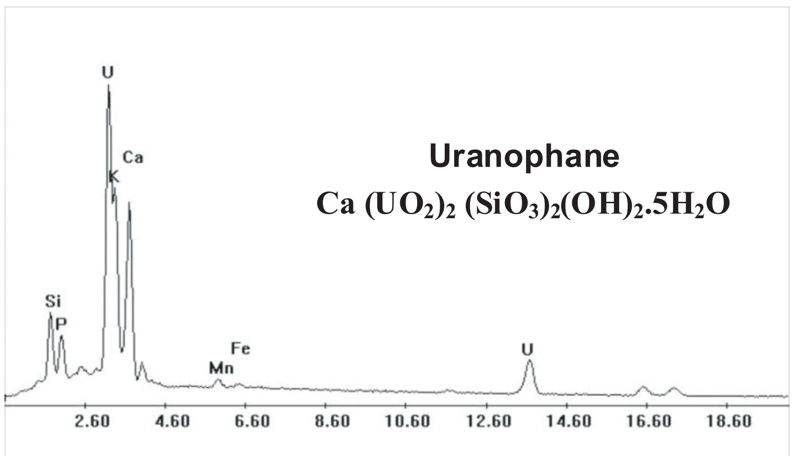


Figure (5.6d): EDAX chart for uranophane by Environmental Scanning Electron Microscope (ESEM).

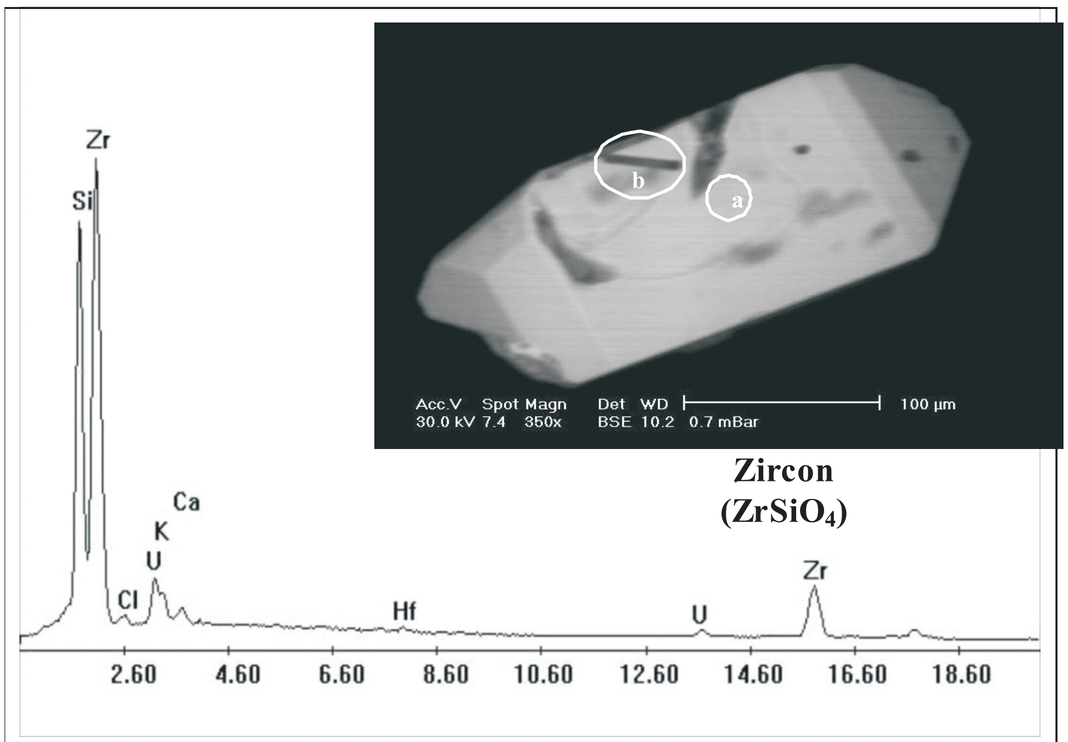


Figure (5.7): Microphotograph by Environmental Scanning Electron Microscope (ESEM) for zircon with inclusions of a) uranophane and b) apatite, with EDAX chart for zircon.

## 5- CONCLUSIONS

The Dokhan volcanics of Gabal Nuqara and Gabal Abu Aqarib are subdivided into two units: intermediate and silicic volcanics. The silicic unit of G. Nuqara is composed essentially from rhyolite, rhyodacite, dacite and their equivalent pyroclastics. The silicic unit of G. abu Aqarib consists of rhyolite, rhyodacite and rhyodacitic crystal tuffs as a representative pyroclastic. The pyroclastics (noth of G. Nuqara and G. Abu Aarib) contain fragments varying in size from ash to lapilli and sometimes to bombs or huge rock fragments. Tuffs sometimes show kinked lamination; some of these laminae become brick red due to staining with iron oxy-hydroxides. Geochemically, both of the Dokhan Volcanic of G. Nuqara and G. Abu Aqarib have calc-alkaline affinity with alkali enrichment. They were erupted in a volcanic arc tectonic setting at an active continental margin. The average eU content of the silicic volcanic rocks of G. Nuqara and the silicic volcanic rocks of G. Abu Aqarib are 9.4 and 8.5 ppm, respectively, while their average eTh content are 23.1 and 19, respectively. Because of the relatively low average content of uranium, visible mineralization is absent. Uranium is present as a trace within resistate accessory minerals.

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