CHAPTER SEVEN

SUMMARY AND CONCLUSIONS

The present work was held to accomplish part of the program of the Nuclear Materials Authority (NMA) of Egypt, in carrying field radiometric surveying of the Neoproterozoic basement rocks north of latitude 27° 00′, with special emphasis on the younger granitic rocks, as they are the host rocks for uranium mineralization in the Eastern Desert.

The present thesis deals with the field structural mapping, petrography and geochemistry of the granitic rocks, and radioactivity of G. El Resha-W. El Atrash area, in the northern part of the Eastern Desert of Egypt. The area of study (414 Km^2) is delineated by latitudes 27° 06′ 00″ - 27° 15′ 00″ N and longitudes 33° 00′ 00″ - 33° 11′ 30″ E. The main rock types exposed in the area are chronologically arranged, according to their field relations and petrographic studies into: metagabbros (oldest), older granites, Dokhan volcanics, Hammamat sedimentary rocks, younger granites and post granitic dykes (youngest).

The metagabbros occur as small low-lying masses of limited distribution at W. El Atrash. They are recorded in the eastern part of the study area. These rocks are generally, equigranular, coarse-grained and characterized by deep colours of melanocratic colour index. They are cut by the youngest rock types in the study area.

The metagabbros are highly deformed and suffered from severe alteration. The main constituents are plagioclase and amphiboles (hornblende), in addition to relics of pyroxene, still survive within the secondary amphiboles. Sphene, apatite and opaques are the main accessory minerals.

The Dokhan volcanics are widely distributed in the study area. In their type locality of G. Dokhan, these volcanics rest unconformably over the eroded surface of the metagabbroic rocks at W. El Atrash, while the Um Guruf Dokhan volcanics are overlain by thick package of Hammamat sedimentary rocks at W. Abu Harbah. The Um Guruf Dokhan volcanics are cut by G. Al Hamra alkali feldspar granites, with sharp intrusive contact (striking N 50º E and dipping steeply 65º NW toward the volcanics). Also, in the center part of the area, these volcanics are cut by Hmrat El Sorwhyia syeno-to alkali feldspar granites, with sharp intrusive contact, and form roofpendants above the younger granites. In some places, the younger granites sent offshoots and veinlets into these volcanics. The Um Guruf Dokhan volcanics are hard and pervasively jointed.

The volcanic rocks have a wide range of composition. They are generally composed of lava flows and pyroclastics. The lava flows are represented by intermediate (porphyritic andesite, trachy andesite and basaltic andesite) and acidic volcanics (rhyodacite and dacite). The associated pyroclastics are represented by andesitic and rhyodacitic lithic crystal tuffs, andesitic agglomerates and welded tuffs, ignimbrites. Massive columnar jointing is a common surficial characteristic of the ignimbritic rocks.

The Hammamat sedimentary rocks are mainly exposed along the western part of the study area and unconformably overlying the Dokhan volcanics at W. Abu Harbah. Small-scattered exposures are observed at W. Hamad and they have a sharp intrusive contact versus younger granites. The Hammamat sedimentary rocks are known as essentially unmetamorphosed sediments of continental origin deposited in intermountaineous troughs (El Ramly, 1972).

The succession of the Hammamat sedimentary rocks consists of green to grayish green bedded series of conglomerates, conglomeratic breccias, greywackes, sandstones, siltstones and some bands of the purple slates interbedded with dark grey siltstones and sandstones. These slates are highly fissile, light purple to reddish violet in colour and fine-grained. The conglomerates include pebbles of basic and felsic volcanics, porphyritic volcanics, granodiorites and diorites. The greywackes consist of angular to subangular quartz, feldspars and rock fragments of Dokhan volcanics, embedded in a fine matrix of the same constituents and clay. Sandstones consist of mosaic grains of angular crystals of feldspars and quartz, with some biotite crystals. These components are cemented by thin matrix of sericite, chlorite, fine-grained quartz and opaques. The siltstones are composed of angular to subangular very fine-grained quartz and feldspar, embedded in a very fine matrix of argillaceous material, chlorite and opaques. The purple slates consist of silty-sized quartz grains as well as hematite and sericite, forming alternating fine and very fine laminae.

The studied granitic rocks comprise the two well-known groups in Egypt namely; the “Older granites” and “Younger granites” (El Ramly and Akaad, 1960). In the area under consideration, the older granites are represented mainly by granodiorites, while the younger granites include monzogranites (Salaat El Atrash), syeno-to alkali feldspar granites (Hmrat El Sorwhyia) and alkali feldspar granites (G. El Resha and G. Al Hamra).

The granodiorites are encountered at the southern and southwestern parts of the studied area as low hills with gentle slopes. They are exfoliated and highly jointed, with joint surfaces showing crushing and erosion. These rocks are medium to coarse-grained of light grey to

greenish grey colour, with mesocratic color index and slightly altered. They are cut by the Dokhan volcanics, younger granites and dykes, and are themselves intruding the metagabbros taking xenoliths of them.

The granodiorites rocks are holocrystalline, equigranular and showing hypidiomorphic texture. They consist mainly of plagioclase, quartz, K-feldspar, biotite and hornblende. Sphene, zircon, apatite and opaques are the main accessory minerals. Sericitization, kaolinitization and chloritization as alteration products are observed in the most of the examined samples.

The younger granites are the main rock type in the study area. They are represented by Salaat El Atrash plutons, Hmrat El Sorwhyia plutons and El Resha and Al Hamra plutons. They differ in their morphology, petrography, chemistry and radioactive properties.

Salaat El Atrash monzogranites are exposed at the southeastern corner of the mapped area and also occur in the west as small low hills. They intrude and carry the granodiorites as roofpendants and intrude the Dokhan volcanics taking xenoliths of them. These rocks are coarse-grained, pinkish white in colour and composed of plagioclase (oligoclase), K-feldspars (perthites), quartz and biotite, with subordinate amounts of hornblende. Chlorite, sericite, kaolin are secondary minerals whereas zircon, apatite, sphene and opaques are the main accessory minerals. The presence of the two feldspar phases, plagioclase and perthite, suggests the formation under subsolvus conditions. The presence of perthite indicates the low temperature crystallization of this granite.

Hmrat El Sorwhyia syeno-to alkali feldspar granites are exposed at the central and north parts of the mapped area, covering a large sector of it. These granites intrude the Dokhan volcanics of G. Um Guruf from its northern part and carrying the Dokhan series as roofpendant. They are

clearly intruded by alkali feldspar granites of G. El Resha from its Eastern margin, with sharp intrusive contact between them.

The most characteristic feature of these granites is the lack of the ferromagnesian minerals, giving the rock its leucocratic nature and is characterized by perthitic feldspars. They are medium to coarse-grained and pale pink to faint brownish pink in colour, while the more alkalic type of them exhibits pink to reddish pink colour. Ferromagnesian minerals are found in minor amounts. These rocks are holocrystalline, equigranular and essentially composed of K-feldspars (perthites), quartz, plagioclase and biotite. Chlorite, sericite and kaolin occur as secondary minerals. Zircon, sphene, allanite, apatite and opaque are the main accessory minerals.

G. El Resha and G. Al Hamra alkali feldspar granites are well exposed along W. El Atrash at the eastern and southeastern parts of the area and small outcrops exist at the western boundaries of the area. They intrude the older granites, Dokhan volcanics of G. Um Guruf and the younger granites of Hmrat El Sorwhyia. These rocks are fine-grained, reddish pink to red colour, leucocratic, hard and massive. They are composed of quartz and potash feldspar, with subordinate amount of plagioclase range in composition from oligoclase to albite. Chlorite, sericite and kaolin are secondary minerals. Accessory minerals in this type of granite are mostly zircon, apatite, allanite and opaques.

G. El Resha and G. Al Hamra alkali feldspar granites contain much potash feldspar than syeno-to alkali feldspar granites of Hmrat El Sorwhyia. Feldspars are mostly masked by reddish brown hematitization (iron oxides staining). These rocks are generally characterized by well-defined graphic texture.

Detail structural investigations reveal that the area of study has been subjected to several tectonic events. These tectonic events gave rise to many structural features mainly represented by joints and faults.

The statistical analysis and the obtained stereographic projection of joints revealed that each rock type is characterized by a definite significant joint pattern. This could be related to their different physical properties and strain abilities. It could be also due to the implication of more than one tectonic event on the same rock type. The main trends of these joints are NE-SW, NW-SE and ENE-WSW. The main faulting type in the area is the strike-slip faults. The faults exhibit NNW-SSE, NE-SW and N-S trends. The NE-SW, N-S, and ENE-WSW trends represent the main structural trends controlling the tectonic framework of the studied area.

Geochemically, the older granitoids have lower SiO_2, K_2O, Rb, Nb, Zr and Y and higher FeO_t, MgO, CaO, TiO_2, Ba, Sr and Ni than the younger granites. They are metaluminous, calc-alkaline typically I-type and formed in volcanic arc tectonic setting (i.e. Pre-plate collision) under compressional forces. They are intruded in a thickness crust of 20-30 km at water vapour pressure >2kb and crystallized at temperatures ranging from 1000º C to 1050º C.

On the other hand, the studied younger granites have higher contents of SiO_2, K_2O, Na_2O, Rb, Nb, Zr, Y and Pb and lower contents of TiO_2, Al_2O_3, FeO_t, MnO, MgO, P_2O_5, L.O.I., Ba, Sr, and Ni than the studied older granitoids. These results are characterisitic of late-differentiate granites emplaced at the end of the Pan-African orogenic activity in Egypt (Hassan and Hashad, 1990).

The studied monzogranites are considered as I-type and originated from peraluminous calc-alkaline, high fractionated magma. They are

considered as syn-collision granites and formed under a compressional tectonic regime. They are intruded in a thickness crust of 20-30 km at water vapour pressure between 1.75 to 2.0 kb and crystallized at temperatures ranging from 850º C to 900º C.

The syeno and alkali feldspar granites are considered as I-type and originated from peraluminous calc-alkaline highly fractionated magma. They are considered as post-orogenic granitoids (POG) and formed under an extensional tectonic regime, suggesting crystallization during relaxation stage that following collision. They are intruded in a crust of thickness greater than 30 km at water vapour pressure between 1 and 1.5kb and crystallized at temperatures ranging from 800º C to 850º C.

The values of differentiation index (D.I.) in the older granitoids range from (66.96 to 70.94) with an average (69.16) while in the studied monzogranites range from (85.44 to 85.71) with an average (85.55). These values are much lower than the D.I. of all the studied syeno and alkali feldspar granites (92.70 to 96.01), with an average (94.41). This wide and obvious D.I. gap suggests that these granites are genetically completely independent.

The emplacement of the younger granites was usually followed by the intrusion of number of dyke suites. These dykes of variable attitudes, dimensions and compositions and dissect all the rock types exposed in the studied area. They are mainly felsic dykes (granite porphyry, granophyres, rhyolite and dacite) and mafic dykes (andesite, dolerite and Basalt). The NE-SW trend is the most predominating trend of the dykes in the area, followed by the ENE-WSW and N-S trends. The dykes run in parallel to sub-parallel swarms and generally follow the prevailing structural system.

Concerning the radioactivity in the various rock types in the studied area, there is a close relationship between the intensity and distribution of radioactivity and the lithology and structure pattern of the rocks. The younger granites have higher radioactive values compared with the metagabbros, granodiorites, Dokhan volcanics and Hammamat sedimentary rocks. Radioactive concentrations are associated mainly in areas suffered from intense fractures dissecting the granites and in areas characterized by highly alteration including hematitization and kaolinitization. Hmrat El Sorwhyia syeno-to alkali feldspar granites have Th/U equal 2.6 while G. El Resha and Al Hamra alkali feldspar granites have Th/U equal 2.1. These ratios are lower than Th/U ratios of the world averages. This means that the younger granites in the study area are enriched in uranium relative to thorium.

The radioactive equilibrium studies show a case of equilibrium state in most cases of the present older rocks, while the younger rocks show disequilibrium state.

Two radioactive anomalies are recorded in the studied area. They are associated with pegmatites in Hmrat El Sorwhyia syeno-to alkali feldspar granites. The NNW-SSE and ENE-WSW joint trends are the most important trends controlling the distribution of the high radioactive anomalies in the area. The first anomaly has gamma radioactive values varying from 133 to 167 Ur, eU content equal to 21 ppm and eTh equal to 84 ppm. The second anomaly has gamma radioactive values varying from 150 to 2403 Ur, eU content equal to 3541 ppm and eTh equal to 16258 ppm.

Zircon is considered as an important radioactive accessory mineral in the studied younger granites especially pegmatites. Also, opaques play a significant role in capturing uranium from circulating solution.