CHAPTER ONE

1. INTRODUCTION

1.1. General Statement

One of the major requirements to sustain human progress is an adequate clean source of energy. Uranium is the icon of the nuclear age, and considered as the essential fuel for the nuclear power reactors. This fact led to a rapid expansion in the exploration of uranium ore worldwide.

The exploration efforts, carried out by the Nuclear Materials Authority of Egypt (NMA) at Gabal (G.) Gattar area, led to the discovery of more than ten uranium mineralized occurrences named, according to date of discovery, G-I, G-II, G-III, G-IV, G-V…etc (Figs. 1.1&1.2). The uranium mineralization at most of these occurrences is related to the granite itself and consequently considered as intragranitic uranium occurrences.

G-V uranium occurrence represents a perigranitic uranium mineralization, as it is entirely related to the contact zone between the Hammamat sedimentary rocks and G. Gattar granite, but mainly developed within the former. This unique situation has attracted the attention to select this occurrence, G-V, for detailed investigations.

1.2. Synopsis of the Egyptian Basement rocks

The Precambrian basement rocks of Egypt occupy the northwestern part of the Arabian-Nubian shield that represent the northeastern sector of the U-shaped Pan-African orogenic belt (Fig. 1.3). These rocks cover about one tenth of the land surface, forming extensive mountain masses in the Eastern Desert, southern part of Sinai, and small isolated outcrops to the south of the Western Desert of Egypt.

1.2.1. Classification of the Egyptian basement rocks

Several studies have been achieved by many authors to classify the Egyptian basement rocks, among them are: Hume, 1935; Schürmann, 1953, 1955&1966;

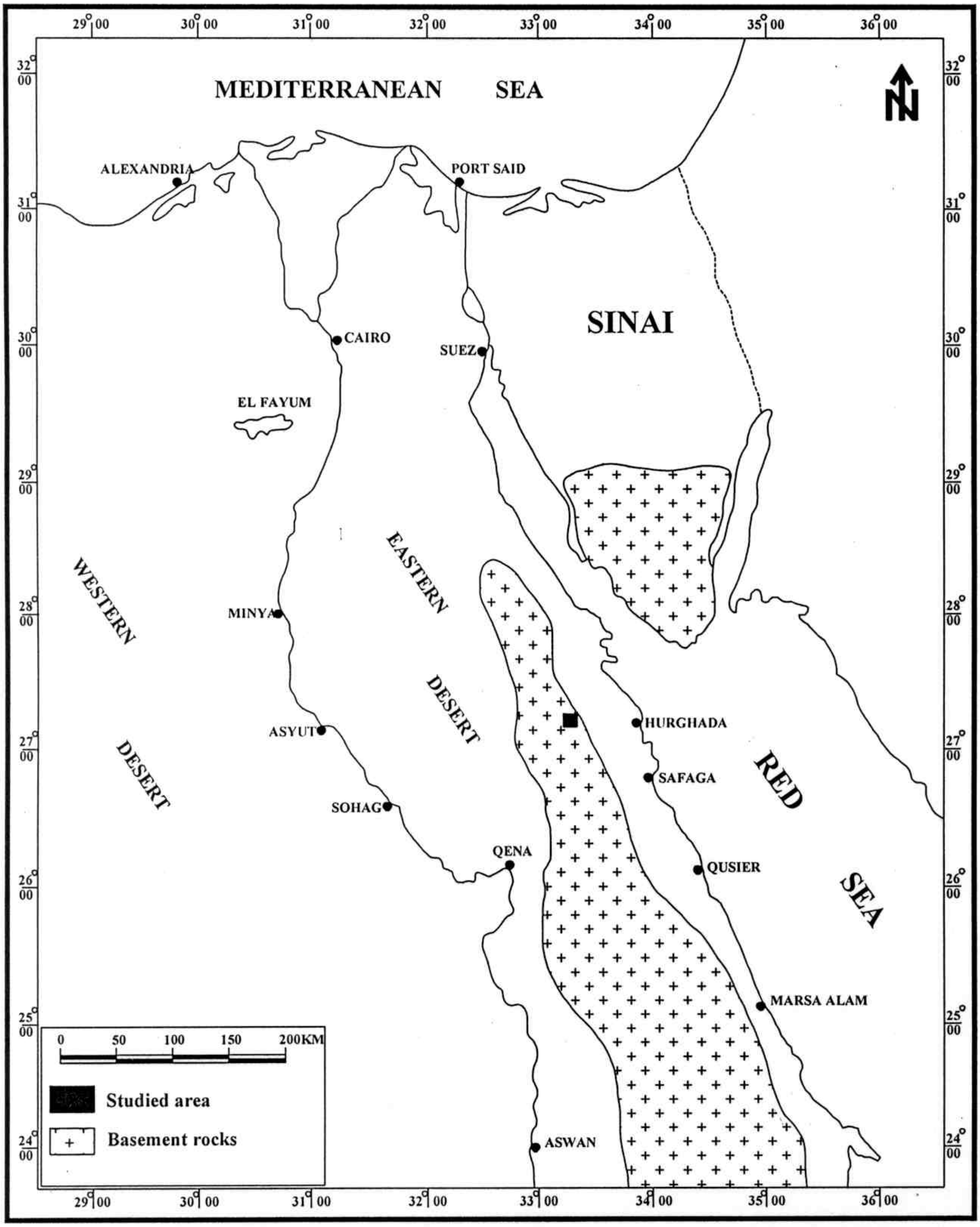

Fig. 1.1: Location map of G. Gattar uranium prospect, North Eastern Desert, Egypt.

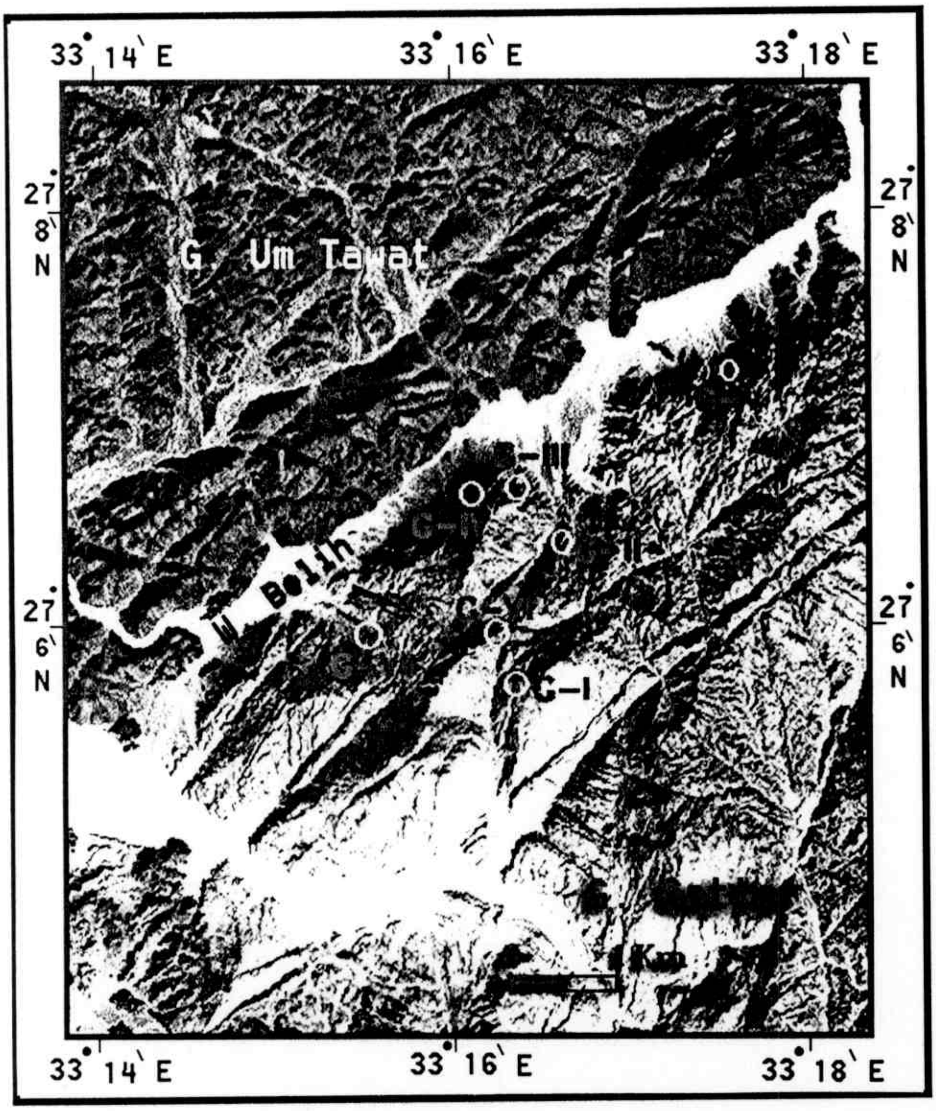

Fig. I.2: Land sat image showing G. Gattar uranium prospect and the location of the promising uranium occurrences.

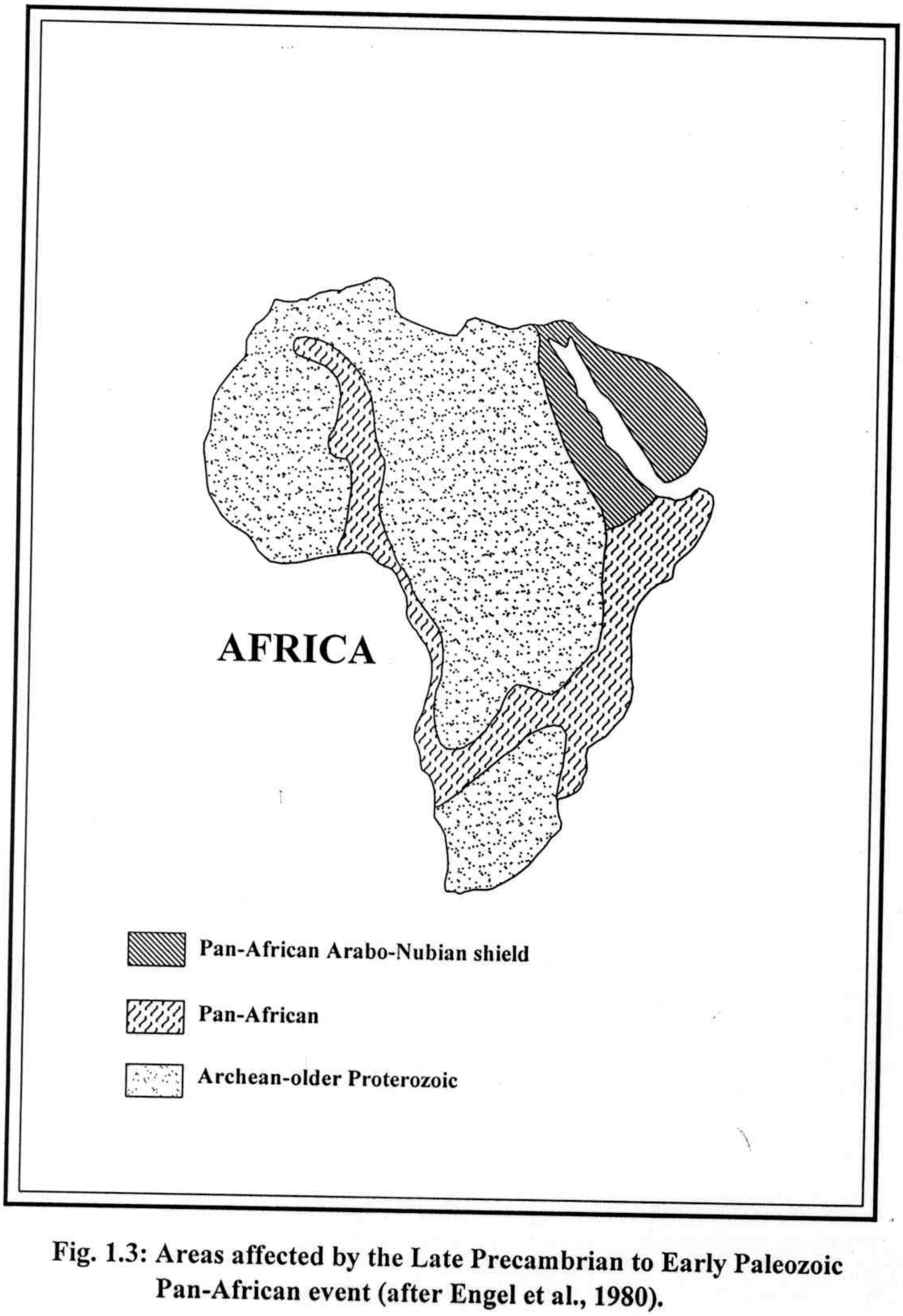

Fig. 1.3: Areas affected by the Late Precambrian to Early Paleozoic Pan-African event (after Engel et al., 1980).

El Ramly and Akaad, 1960; El Shazly, 1964; El Ramly, 1972; Akaad and Noweir, 1969&1980. They established a satisfactory geochronological classification of the basement complex of Egypt within the frame of the geosynclinal concept that was prevailing at that times.

In the last decades, many studies were published on the ophiolitic assemblages within the Precambrian rocks of the central and southern parts of the Egyptian Eastern Desert (e.g. El Sharkawi and El Bayoumi, 1979; Dixon, 1981; Stern, 1981; Takla et al., 1982; Ries et al., 1983; El Gaby et al., 1988&1990). These studies focused the attention on the role of the plate tectonics during the Precambrian times on the basement rocks exposed in the Eastern Desert. Since then, the Egyptian basement complex has been reinterpreted as a product of late Proterozoic crustal evolution (950-550Ma; Kröner, 1985), which was termed as Pan-African Crustal Evolution. Among the two concepts, geosynclinal and plate tectonics, the most adopted and common of these classifications are summarized in Table (1.1).

1.2.2. Classification of the Egyptian granitoids

The granitic rocks are the most predominant types among the Egyptian basement rocks. They constitute about 60% of the total basement terrain of the Nubian shield in Egypt (Stern and Hedge, 1985). The Egyptian granitoid rocks attracted the attention of many workers, thus many classifications have been proposed for them. These classifications led to the recognition of two main granite groups, namely the older and younger granitoids (Table 1.2).

1- The older granitoids: are commonly known as "*Grey granites*" by Hume (1935); "*Shaitian granites*" by Schürmann (1953), "*older granites*" by El Ramly and Akaad (1960) and Akaad and Noweir (1969&1980). These granitoids are also referred to as "*Syn-orogenic plutonites*" by Sabet (1962), El Shazly (1964), El Ramly, (1972), El Gaby (1975) and Ries et al., (1983), "*Calc-alkaline granites*" by El Gaby, (1983), "G_I*-granites*" (subduction-related) by Hussein et al. (1982) and "G_α*-granites*" by El Gaby et al. (1988&1990).

Table (1.1): **The most common classifications of the Egyptian basement complex based on the geosynclinal and plate tectonic concepts.**

Geosynclinal concept		Plate tectonic concept	
El Ramly and Akaad (1960)	**Akaad and Noweir (1980)**	**Ries et al. (1983)**	**El Gaby et al. (1988&1990)**
Alkaline volcanic suite Post granite dykes	Kab Absi Essexite Gabbro Khors volcanics	Alkali granites	Sualkaline to peralkaline silicic Igneous rocks
Younger granites Igla Formation	Younger granites Post-Hammamat felsites Hammamat Group	Younger granites Hammamat group	Tectonogenetic association: calc-alkaline granites (G_{γ} and G_{β}), Dokhan volcanics, molasse Hammamat sediments and Iherzolite-gabbro-diorite
Volcanics (Dokhan type)	Dokhan volcanics	Calc-alkaline volcanics include the Dokhan volcanics	
Grey granites	Older Granites	Syn-tectonic to late-tectonic granodiorites, diorites, tonalites, quartz diorites.	
Epidiorite-diorite association, serpentinites and related rocks Metavolcanic series Schist-mudstone-greywacke series	Rubshi Group Sid Metagabbro Barramiya Serpentinites Abu Ziran Group (Eugeosynclinal fillings): classified into 8 formations of metasediments and meta volcanics Abu Fannani Schist	Eastern Desert ophiolitic melange Meatiq group: Arkosic metasediments of continental shelf facies	Pan-African ophiolites and island arc assemblage. Pre Pan-African gneisses and schists and their mylonitized and remobilized equivalents
Migif Hafafit gneisses	Meatiq group of gneisses and migmatites		

Table (1.2): The different tectonic classifications of the Egyptian granitoid rocks.

<table>
<tr><th>Author (s)</th><th>Older granitoids</th><th colspan="4">Younger granitoids</th></tr>
<tr><td>Hume (1935)</td><td>Grey granites (older phase)</td><td colspan="4">Qattarian granites (younger suite)</td></tr>
<tr><td>El Ramly and Akaad (1960)</td><td>Older grey granites</td><td colspan="4">Younger pink and red granites</td></tr>
<tr><td>El Shazly (1964)</td><td>Syn-orogenic plutonites</td><td colspan="2">Late-orogenic plutonites</td><td colspan="2">Post-orogenic granites</td></tr>
<tr><td>El Gaby (1975)</td><td>Syn-orogenic granitoids</td><td colspan="4">Late-to post-orogenic granitoids</td></tr>
<tr><td>Hussein et al. (1982)</td><td>G-1 Subduction related granites</td><td colspan="2">G-2 Suture related granites</td><td colspan="2">G-3 Anorogenic granites</td></tr>
<tr><td>El Shatoury et al. (1984)</td><td>A-granites</td><td colspan="2">B1-granites</td><td colspan="2">B2-granites</td></tr>
<tr><td>Stern et al. (1984)</td><td>Mesozonal plutons
(Calc-alkaline and subduction-related)</td><td colspan="4">Epizonal plutons
(Alkaline to peralkaline rift-related granites)</td></tr>
<tr><td rowspan="2">El Gaby et al. (1988,1990)</td><td colspan="3">Syn-to late orogenic series subduction-related</td><td colspan="2">Post-tectonic series
Anorogenic setting</td></tr>
<tr><td>G_α calcalkaline tonalite-granodiorite</td><td colspan="2">G_β calcalkaline ideal granites</td><td colspan="2">G_γ subalkaline to peralkaline granites</td></tr>
<tr><td>Hassan and Hashad (1990)</td><td></td><td>Volcanic arc setting</td><td colspan="2">Arc-continent collision (late-orogenic)</td><td>Post-cratonization rifting</td></tr>
<tr><td>Takla and Hussein (1995)</td><td>Older granitoid "GI" diorite-tonalite-granodiorite association</td><td colspan="4">Younger granites "GII" continental margins and within plate granites</td></tr>
</table>

These rocks are of wide distribution in the Eastern Desert where they cover the compositional spectrum of quartz diorite, tonalite, granodiorite and rarely true granites (El Gaby, 1975). The age of these granitic rocks is ranging between 626±2 and 780±7Ma (Dixon, 1981; Sturchio et al., 1983; Gillespie and Dixon, 1983). For most of these granitoids, a subduction-related mechanism has been suggested for their generation (Hussein et al., 1982; Furnes et al., 1996; Moghazi, 1999).

2- The younger granitoids: are described as "*Gattarian granites*" by Hume (1935), "*Pink granites*" by Schürmann (1953), "*Younger granites*" by El Ramly and Akaad (1960) and Akaad and Noweir (1969&1980), "*Late-orogenic plutonites*" by El Shazly (1964), "*G_2-granites*" by Hussein et al. (1982), "*Calc-alkaline younger granites*" by El Gaby (1983) and "*G_β-granites*" by El Gaby et al. (1988&1990)). Alkali granites, sub-type of the younger granites, are of limited distribution and they are referred to as "*G3-granites*" by Hussein et al. (1982), "*Younger post-tectonic alkaline to peralkaline granites*" by El Gaby (1983), "*B2 granites*" by El Shatoury et al. (1984) and "*G_γ granites*" by El Gaby et al. (1988&1990).

The younger granites represent the second major group of granitic rocks in the Egyptian basement complex. They are widely distributed all over the Egyptian shield, constituting approximately 30% of its plutonic assemblage (Hassan and Hashad, 1990). Field, petrological and geochemical studies as well as the structure and mode of emplacement of these granitoids have been carried out by many authors and led to the recognition of more than one phase (group) of the younger granites. There are many tectonic models that were suggested for the emplacement of these granitoid rocks such as late-orogenic, post-orogenic, anorogenic rift-related (Table 1.2).

The age obtained for the Egyptian younger granites ranges from 568 to 597Ma (Fullagar and Greenberg, 1978; Fullagar, 1980; Hashad, 1980) and may be extending to 622Ma (Meneisy and Lenz, 1982) or 641Ma (Moussa, 1998).

1.2.3. The Hammamat sedimentary rocks

Numerous investigations on the Hammamat sedimentary rocks at various localities in the Eastern Desert have led to a much better understanding of their maturity and depositional history. These studies include texture and color investigations (e.g. Akaad, 1957; Akaad and El Ramly, 1958; Akaad and Noweir, 1969), stratigraphic classifications (e.g. Akaad and Noweir, 1980; Khudeir and Ahmed, 1996), facies classifications (e.g. Francis, 1972; Samuel, 1978; Grothaus et al., 1979; Rice et al., 1993) and structural investigations (e.g. Messner, 1997; Fritz, 1999; Shalaby et al., 2006).

These studies concluded that, the clastic sedimentary rocks are typified by the Hammamat group and represent the most famous sedimentary assemblage in the Precambrian basement complex of the Eastern Desert of Egypt (Akaad and Noweir, 1980). The Hammamat sedimentary rocks, of molasse type, were deposited in discontinuous intermountain basins, as a result of the rapid uplift and erosion in fresh water environment (Grothaus et al., 1979). These rocks are compositionally and texturally semimature to immature, reflecting deposition close to their provenance (Willis et al., 1988). The Hammamat sedimentary rocks occur as series of isolated outcrops in the Eastern Desert of Egypt, which lies unconformably above the Dokhan volcanics and intruded by a wide spectrum of igneous rocks of varying composition (Akaad and Noweir, 1978).

1.3. Area of Study

1.3.1. Location

G–V uranium occurrence locates about 35km to the west of Hurghada city, at the Red Sea coast (Fig.1.1). It can be reached from the Red Sea coast highway through Wadi (W.) Belih desertic motorable road. This occurrence is approximately determined by the intersection of the latitude $27^{o}\ 07^{\backslash}\ 18^{\backslash\backslash}$ N and the longitude $33^{o}\ 17^{\backslash}\ 42^{\backslash\backslash}$ E. It situates at the northern parts of G. Gattar pluton, along its contact with the Hammamat sedimentary rocks of G. Um Tawat, through W. Belih (Fig. 1.2).

1.3.2. Topography

A topographic map, scale 1: 2000 has been prepared for the area under study (Fig. 1.4). It is clear from this map that the topography of the area is more affected by its lithology and structures. The granite of G. Gattar, on the southern parts, shows moderate to high resistance to weathering agents and usually forms moderately to high-elevated summits with rugged peaks. In the contrary, the Hammamat sedimentary rocks on the northern parts show different grade of erosional effects due to their wide range of composition and the structures affecting them. They occur as thin elongated strips of low to moderate elevation and their slopes are usually covered with dark fragments. On the other hand, W. Belih mostly runs along NE-SW direction through the southern parts of G. Um Tawat and the northern portion of G. Gattar pluton. The width of W. Belih reaches to about 400m along the investigated area; the Wadi floor is mainly covered with Quaternary sediments.

1.3.3. Previous works

Many researchers studied the regional geology of the basement rocks exposed in the Eastern Desert of Egypt, including the studied area. A historical review of the most important and recent publications on the present area will be stated in the following pages:

Schürmann (1966) divided the Qattarian granites into lower and upper Qattarian with Hammamat formation in between. The upper Qattarian granite is represented by the younger granites while the lower one is described by the surrounding granites and granodiorites.

Rasmy (1969) stated that the granite of G. Gattar is leucogranite, alaskitic in composition, very poor or nearly free from ferromagnesian. She added that some samples are rich in quartz than the normal granite and may be due to later enrichment.

Dardir and Abu Zeid (1972) defined G. Gattar granite as composed of quartz and perthitic orthoclase in nearly equal amounts together with oligoclase and

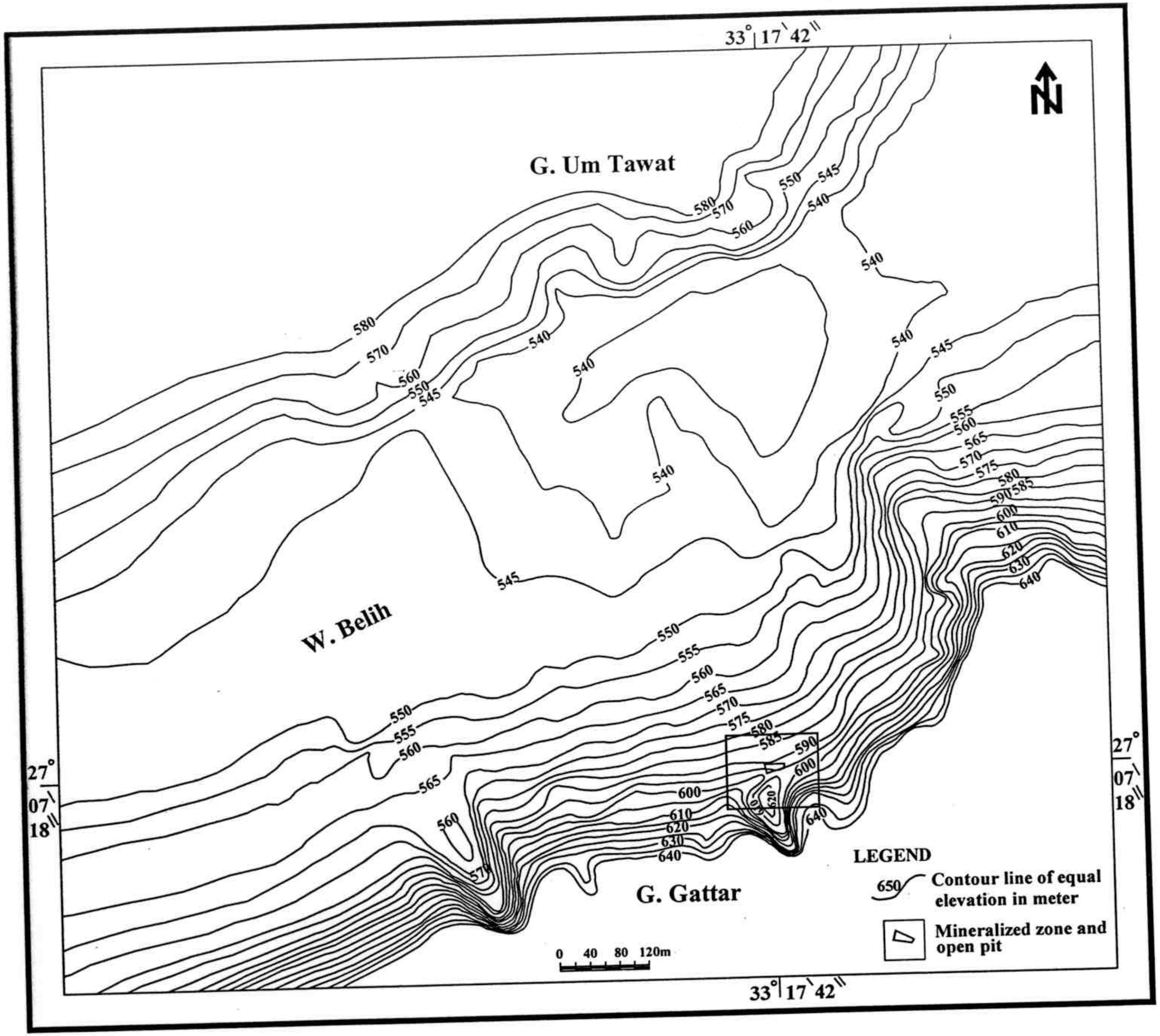

Fig. 1.4: Topographic contour map of G-V uranium occurrence.

biotite. They concluded that the sedimentary rocks of G. Um Tawat represent the basal part of the Hammamat group and include conglomerates, greywackes and siltstones.

Hashad (1980) in his review of isotopic age for the rocks of the Egyptian basement complex assigned an age of 484Ma, to G. Gattar granite. He delineated two major episodes of igneous activity: the older one covers a span of time of 1000 to 850Ma and the younger episode covers the period between 675 and 500Ma.

Stern and Hedge (1985) identified six principle magmatic events throughout the Eastern Desert, based on their geochronologic framework. They detected the age of G. Gattar granite to about 573Ma, using the Rb-Sr method. They added that, Salat El Belih granodiorite, NE of G. Gattar, appears to be older than the granite of G. Gattar, and has age of 583Ma (zircon analyses).

Salman et al. (1986) presented a radiometrical map for the northern sector of G. Gattar area. They pointed out that the uranium mineralization, in G. Gattar area, is present in a patchy form, which are structurally controlled by NE-SW and NW-SE fault trends; the secondary uranium mineralization increases at the intersection zone of these two trends.

Moghazi (1987) showed that the Hammamat sedimentary rocks at W. Belih are composed of intercalations of siltstones, quartz arenites and greenish greywackes, which unconformably overlie the andesites pertaining to the Dokhan volcanics.

Willis et al. (1988) determined the age of the Hammamat sedimentary rocks of the present area of about 585±15 Ma, which is interpreted to be approximately close to the time of sedimentation.

El Rakaiby and Shalaby (1988) indicated that G. Gattar batholith is composed of three granitic phases; G1, G2, and G3, based on different mineralogical compositions, different reliefs, and surface textures. They added that the uranium and molybdenum mineralizations are associated with G3 phase of this granite, which they considered to be the youngest phase.

Attawiya (1990) proposed that G. Gattar granite is originated from a peraluminous calc-alkaline magma with some alkaline affinities. He also concluded that the geochemistry of the trace elements indicates a within-plate magmatic (anorogenic) tectonic setting for this granite.

Mahdy et al. (1990) in their leaching studies on the uranium mineralization of the Hammamat sedimentary rocks from G-V uranium occurrence; stated that the uranium mineralization is completely leached by using sulfuric acid at a concentration of 100 g/L. They used X-Ray diffraction technique to identify some secondary uranium minerals such as uranophane and tyuyamunite.

Shalaby (1990) investigated the uranium mineralization at the contact zone between G. Gattar and the Hammamat sedimentary rocks along W. Belih. He concluded that the uranium mineralization of G-V occurrence is essentially controlled by a local reverse fault trending ENE-WSW and dips 45°-65° to the SSE.

Sayyah and Attawiya (1990) carried out a mineralogical study on some samples collected from G-II exploratory mine, G. Gattar uranium prospect. They identified uraninite, as the only primary mineralization, in addition to clarkeite, zippeite, carnotite, uranophane, soddyite, kasolite, as secondary mineralization.

Roz (1994) presented geological, structural and radiometrical studies of G. Gattar area with detailed studies on some uranium occurrences. He pointed out that the radioactivity generally increases at the intersection of fractures, whereas the visible secondary uranium mineralization is found. He concluded that G. Gattar uranium prospect could be classified as hydrothermal vein-type uranium mineralization.

Abu Zaid (1995) clarified the relation between structures and uranium mineralization of G. Gattar area. He specified that G-I, G-II and G-VI uranium occurrences locate within a large pull-apart basin. Such structure played as passways to the ascending hydrothermal solutions carrying uranium mineralization for the different uranium occurrences.

Haridy (1995) payed attention to the relation between the physical and mechanical properties and the spatial distribution of the joint-type uranium mineralization in G. Gattar area. He statistically treated the field measurements of the structural elements affecting both the granite and the Hammamat sedimentary rocks and delineated the paleostress that affecting the area. He also determined the chronological sequence of these paleostress and then described the structural evolution of G. Gattar area.

Shalaby (1995) determined the factors governing uranium mineralization at the various occurrences of G. Gattar area. These factors are the favorable mineralogical composition of the granite, high magmatic uranium background and the presence of suitable structural traps for mineralization.

Shalaby (1996) studied the structural elements that control the uranium mineralization at G. Gattar area. He mentioned that the various uranium occurrences of G. Gattar are mostly controlled by NNE-SSW sinistral faults, dipping from 65° to 85° to the ESE direction and NW-SE dextral faults, dipping between 70° and 80° to the NE direction.

Nossair (1996) in his study on the contact zone of G-V uranium occurrence; stated that both the granite and the Hammamat sedimentary rocks were affected by U-F bearing circulating solutions. These solutions are most probably derived from granite through N-S and NNE-SSW peripheral fractures under low epithermal conditions in a shallow level.

Holail and Moghazi (1998) compared the Hammamat sedimentary rocks exposed at W. Hammamat with that of W. Belih. They confirmed that the Hammamat sedimentary rocks of W. Belih were derived from a relatively homogenous source; composed of 90% intermediate volcanics and 10% felsic volcanics. They added that the presence of rock fragments older than the Dokhan volcanics among the Hammamat sedimentary rocks of W. Belih suggested that their deposition were in a closed intra arc basin, while the Dokhan volcanics were the main source of the clastics.

Mahdy (1999) demonstrated by field observation, petrographical and geochemical studies, a genetical model for the uranium mineralization at G-V uranium occurrence, which is similar to that proposed by Leroy (1978), but with some modification.

Shalaby and Moharem (2001) determined the average of U and Th content in the fresh samples of the Hammamat sedimentary rocks, at the southern part of G. Um Tawat, as 8.4 and 5 ppm respectively. On the other hand, the average [U and Th] content in the altered Hammamat sedimentary rocks are 2091 and 10.3 ppm respectively, indicated an enrichment of U and Th in the altered Hammamat.

El Zalaky (2002) suggested that the emplacement of Gattar pluton has led to the formation of weak zones, fractures and faults around the peripheral parts, which facilitate the action of the hydrothermal solution that carrying the uranium mineralization. He also delineated two phases of ductile deformation. The first one is developed pre-dating the intrusion of Gattar pluton, while the second phase is related to and formed due to the effect of the emplacement of Gattar pluton.

El Sayed et al. (2003) classified the granites of G. Gattar area into mildly alkaline subsolvus and alkaline hypersolvus granite. They added that the hypersolvus granite has higher contents of [Rb, Y and Nb] and lower contents of TiO_2, Sr, Ba and REE and has more pronounced negative Eu anomalies than the subsolvus granite. They considered the subsolvus granite of post-orogenic (A_2-subtype), while hypersolvus granite of anorogenic (A_1-subtype).

El Dabe (2004) in his discussion on the origin of the granitoid rocks of G. Salaat El Bali and G. El Reddah environs, northeast G. Gattar; indicated that G. Gattar granite originated from a peraluminous alkaline, highly fractionated intra plate A-type granite; developed in extensional environment.

Nossair (2005) achieved a comparative structural study of both surface and subsurface at G-II uranium occurrence. He concluded that the predominant joint and fracture trends recorded at the topographic surface are still persistent and nearly possess the same intensities at the subsurface, escorted with the same types of alteration features.

Youssef (2005) carried out a pronounced study of detrital zircons on the Hammamat sedimentary rocks of G. Gattar-G. El Dokhan area. The results indicate maximum depositional age of 585±13Ma; and suggested an extensional environment for these sedimentary rocks.

1.3.4. Scope and Objectives of the Present Work

The present study principally deals with the possible factors controlling the radon emanation related to uranium mineralization along W. Belih with emphasize on G-V uranium occurrence. These factors include the geological, structural, petrological and geochemical ones. Various studies of these factors are the main target of the present work. This will be achieved through the following items:

1- Preparation of a geological and structural map of scale 1: 1000. On this map, the various rock types and structural features are illustrated.
2- Systematic collection of representative samples of various rock types along some profiles perpendicular to the contact between the Hammamat sedimentary rocks and G. Gattar granite.
3- Study of the major structural features affecting the investigated area; through field observation and measurements as well as statistical treatments.
4- Petrographic studies of thin sections representing the various rock types, to determine their textural features, proper identification and nomenclature, as well as the distribution of uranium mineralization among the rock forming minerals.
5- Geochemical studies to determine the geochemical characters of the Hammamat sedimentary rocks and their hosted uranium mineralization, as well as the granite as a probable potential source or feeder for this mineralization.
6- Application of alpha-track technique to ascertain for subsurface or hidden uranium mineralization.
7- Interpretation of the assembled data to achieve the objectives of this thesis.