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" Geoelectric and Shallow Seismic Investigation for the Assessment of Radioactive Mineral Bearing Horizon in North Ras Millan Area, Southern Sinai Peninsula, Egypt"

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CHAPTER ONE
INTRODUCTION

I.1. General

Sinai Peninsula covers an area of about 61,000 km^2. It is triangular in shape and is bounded by the Suez Canal and the Gulf of Suez from the west, the Gulf of Aqaba from the east, the Mediterranean Sea from the north and the Red Sea from the south. It was subjected to a comprehensive program of the prospection and exploration for radioactive minerals. The program included geological, geochemical and geophysical surveys. The present work demonstrates the integration of geoelectric resistivity sounding, shallow seismic refraction, magnetic and spectrometric techniques, in order to define the subsurface occurrences of the radioactive mineral-bearing horizons in North Ras Millan area, Southern Sinai, Egypt.

I.2. Location of the area

North Ras Millan area is located at Southern Sinai, Egypt, between latitudes 27° 55' & 28° 0' N and longitudes 33° 55' & 34° 0' E (Fig.I-1). It is bounded from the north and east by Wadi Rabud and Wadi Shara, respectively, while the Gulf of Suez bounds it from west and south.

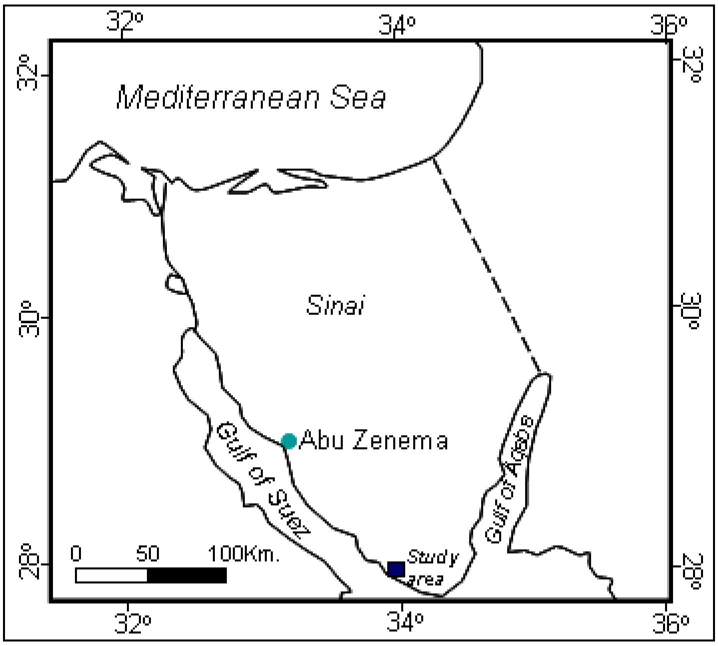

Fig. (I-1): Location map of North Ras Millan area, Southern Sinai, Egypt.

1.3. Topography of the area

Ras Millan area is a NW trending coastal plain located between the Gulf of Suez and the high Precambrian massif of Southern Sinai and representing an extension of El Qaa plain. Topographically, it is a featureless alluvial plain rising gently from sea level to about 400m at the edge of the Precambrian massif. It includes Gabal Khashbi, Gabal Al Gharib, Gabal Sahara and Gabal Mezriya. The general elevation decreases gently from the east to the west.

The area is dissected by many wadies of varying directions. Wadi Mukheirate, Wadi Lethi and Wadi Rabud follow the NE - SW direction, and Wadi El Sharqi and Wadi Madsus trend NW – SE, while Wadi Malaq follows the N-S trend.

1.4 Climate

Sinai Peninsula lies in the North African arid belt, with general conditions including high summer temperatures, mild winters, low humidity and long rainless periods. There are two climatic regions in South Sinai Governorate, the Gulf of Suez is an extension of the Mediterranean coastal conditions; arid, with annual rainfall ranging between 20 and 100mm. The inland highlands and the Gulf of Aqaba are classified as hyper arid with cool winter (mean temperature of coldest month 0-100^{o}C) and hot summer (SEAM Programme, 2003)

Rainfall usually occurs between October and May. Due to the low soil & vegetation cover, steep slopes and high relief, that characterize the governorate, heavy rainfalls can cause major flash floods.

I.5. Aim and Scope of the Study

The main objective of the present study is to delineate the subsurface occurrences of the radioactive mineral-bearing horizons associated with the "D" Member of Arab Formation. It also aims to correlate any surface radioactive minerals with the outcrop in the study area.

To achieve these aims, four ground geophysical techniques were applied; namely, gamma-ray spectrometry, magnetic, shallow seismic refraction and resistivity sounding. The gamma-ray spectrometric method is concerned with the radioactive mineral concentrations for the different rock units in the study area; the ground magnetic survey is carried out to delineate the structural framework and hence the tectonic setting of the study area. The shallow seismic refraction and geoelectrical resistivity surveys help for detecting the subsurface lithology and delineating the probable subsurface occurrences of the radioactive mineral-bearing formation. The integrated interpretation between all geological and geophysical data is used to depict the mode of occurrence and distribution of the subsurface radioactive minerals-bearing formation in the area.

I.6. Methodology

The objectives of the present study can be achieved through the application of the following:-

1. The area is covered by parallel traverse of 50 m. intervals and set normal to the main trend of the wadi with station separation of 25 m. along the traverses. The gamma-ray spectrometric and geomagnetic surveys are conducted along the above described grid pattern.
2. Conducting geoelectric resistivity sounding survey at selected sites in the study area.
3. Conducting detailed shallow seismic refraction survey along selected profiles in the area of study.

I.7. Previous Geological and Geophysical Works

A brief review of the most important contributions carried out in the study area and are given in the following paragraphs.

I.7.1. Geological Studies

Barron (1907) was the first who subdivided the Paleozoic rocks in Southwestern Sinai into Lower Sandstone Series, Carboniferous Limestone Series and Upper Sandstone Series.

Ball (1916) mapped Abu Zeneima area geologically and confirmed Barron (1907) classification.

Abdel Monem et al. (1958) recorded radioactive occurrences in the Lower Sandstone Series of Wadi Al Seih, as small lenses of radioactive black sand.

Gindy (1961) found the relationship between the radioactivity and manganese, iron and copper ore sediments and proposed that, certain phases of the hydrothermal solutions related to the Tertiary volcanicity were responsible for the anomalous radioactivity.

El Sokkary (1963) identified several radioactive anomalies in Southwestern Sinai appearing in definite stratigraphic horizons of the uppermost parts of the Lower Sandstone Series and the Middle Carbonate Series (Um Bogma Formation). He found the principle mineral responsible for radioactivity (Xenotime), that present as minute crystals.

Hilmy and Mohsen (1965) reported that, the Carboniferous rocks of Southwestern Sinai were very much affected by normal faults, which are seen everywhere and vary greatly in lengths and displacements. They considered this area as one of the most disturbed areas in Egypt. The most common trends of these faults, which enclose several grabens and horsts, are N-S and NW-SE.

Omara and Conil (1965) subdivided the Carboniferous Limestone Series in Gabal Nukhul district into the following three members: Lower dolomite Member, Middle dolomite-limestone Member and Upper dolomite Member.

Soliman and Abu El-Fetouh (1969) divided the Lower Sandstone Series from base to top as follows: Sarabit El Khadim Formation, Abu Hamata Formation and Adadia Formation. They considered the Carboniferous Limestone Series of Barron (1907) as Khaboba Formation. Also, they subdivided the Upper Sandstone Series into three formations from base to top: El Hashash Formation, Magharet El Maiah Formation and Abu Zarab Formation.

Weissbrod (1969) gave the term Um Bogma Formation (Early Carboniferious age) to the Middle Carbonate Series. He also renamed the Upper Sandstone Series as the Abu Thora Formation (1980).

El Shazly et al. (1974) studied the geology of Sinai Peninsula from Erts-1 Satellite images and prepared a map for the minerals including copper and uranium minerals. They found two types of copper occurrences guided by the structural patterns. The first one is the copper-bearing Cambrian Sarabit El Khadim Formation and the second is the hydrothermal copper sediments found in the basement of Southern Sinai. Also, they found three targets for uranium exploration, the first one is the sandstone facies extending in age from the Paleozoic to the Paleogene, the second is the pink granites especially these are encountered in the northwestern part of the basement, and lastly the faults and fractures especially in Southern Sinai.

El Aassy et al. (1986) identified some visible secondary uranium mineralizations associated with the Lower Carboniferous siltstone, sandstone and shale at Wadi Nasib, Abu Thor, Allouga, Ramlet Homaier, Wadi Um Hamd and Ras Rahia**.**

El Sharkawi et al. (1990b) found the copper mineralization in the Paleozoic sediments of Southwestern Sinai and postulated that, copper in the form of carbonate, chloride, silicate, sulphate and phosphate minerals is encountered within the Paleozoic sediments of Um Bogma region.

Afifi (1991) studied the geochemistry of some radioactive anomalies at Wadi Nasib and found that, the origin of uranium belongs to the sandstone type.

Amer (1993) discovered the presence of silver metal in the Lower Carboniferous rocks in Gabal Allouga and Abu Thor. He studied the physical and chemical characteristics of uranium mineralization of Southwestern Sinai and investigated the proper treatment of the raw material during leaching and extraction stages of uranium and copper.

Kora et al. (1994) found that, manganese and iron sediments within the Um Bogma Formation were confined to the shaly, silty and carbonates rocks. Also, they added that, they are formed during marine encroachments.

El-Agami (1996) divided the uranium sediments of the Paleozoic rocks in Sinai into three types; paleoplacer sediments, epigenetic sediments and surficial uranium sediments.

Shata (1996) identified the factors affecting the radioactivity of sediments in Southwestern Sinai as follows: Geomorphologic features of the basin of deposition, uranium content and Th/U ratio of sediments, organic matters content, grain size of sediments, dominance of mechanical weathering processes and the alkalinity of groundwater.

Aita (1996) classified the U-sediments in Southwestern Sinai into two main types: strata bound Th-U conglomerate type of Cambrian age, well represented in Gabal Nukhul and strata bound unconformity (paleokarst) related uranium minerals of Carboniferous age, well represented in Talet Seleim and Baba mine localities.

Moustafa (1998) stated that, "the Gulf of Suez depression represents an intensively faulted area". The succession of the strata in different parts of the gulf indicates that the movement was not of the same magnitude in all parts of the gulf and many blocks show varying degrees of activity on their sides. The rift represents the northern arm of the Red Sea and extends for about 300 km in a NNW direction toward Suez City. It is dominated by NNW to NW oriented fault blocks.

Shata (2002) described the Cambro-Ordovician rocks in Ras Millan area and stated that, "they are represented by the Araba Formation, which consists of alternating beds of pebbly to very fine sandstones". He added that, "Araba Formation is unconformably overlies the basement rocks".

Shata (2004) stated that, "Ras Millan structural coastal basin is occupied by Cambro-Ordovician sandstones. These sandstones host uranium mineralization; eU up to 1063 ppm and summation of rare earth mineralization (∑ REE) up to 3483.9 ppm. These mineralizations are related to possible reduced environment along fault zones".

I.7.2. Geophysical Studies

The history of geophysical exploration and development of the study area started in the period between 1936 and 1948, when Standard Oil Company of Egypt carried out gravity and magnetic surveys.

El Kattan (1985) carried out airborne gamma-ray spectrometric studies on Southwestern Sinai area. He divided the area into seven radioactive levels, which generally have spatial correlation with the lithology. These seven radioactive levels have a minimum radioactive value, that goes down to 1uR/h, while the maximum value rise up to more than 20uR/h. On the basis of the quantitative interpretation of the aeroradiometric data, eleven groups of 42 radioactive units have been separated. Also, each of the fore-mentioned groups has its own radioactive level.

El-Eraqi (1992) found the relationship between mineral sediments and structural features in the southwestern part of the Sinai Peninsula, based on analyzing and processing the Bouguer gravity anomalies.

Abu El Ata and Ismail (1999) carried out geoelectric resistivity sounding survey at El-Qaa plain, southwestern coast of Sinai Peninsula**.** They subdivided the Quaternary section at El-Qaa plain into four layers, based on geoelectric analysis. The results of this survey proved that, the resistivity values show a clear picture of the sea water invasion. The resistivity values decrease westwards toward the Gulf of Suez, reflecting the effect of sea water intrusion.

Abdel Aziz (2000) analyzed the aerial magnetic and multi-channel gamma-ray radiometric survey of Abu Zeneima- Al Tur. He qualitatively interpreted these data, based on color differences in color composite image maps, and revealed six uranium leads. These leads are associated with the Cambrian of Araba Formation, Lower Carboniferous of Um Bogma Formation, Lower Carboniferous of Abu Thora Formation, Cretaceous of Duwi Formation, Lower Eocene of Thebes Formation and

Middle-Lower Miocene of Alaqah Formation. He considered the Um Bogma uranium lead as a good target for radioactive mineral exploration.

Nigm et al. (2001) applied the electric and seismic tools to delineate the Um Bogma Formation in Talet Seleim area, Southwestern sinai. They could distinguish the extension and the structures controlled the concerned rock unit. They found that, the thickness of this unit is variable and increases towards the northwest to about 30 m, and diminishes to less than 10 m to the southeast.

Shaheen (2001) indicated that, the Adadia, Um Bogma, Abu Thor and Sudr Formations carry a weak to very weak natural remanent magnetization. He mentioned that, Basaltic sheet samples gave the highest magnetic susceptibilities, Abu Thora Formation samples gave inhomogeneous susceptibilities, Um Bogma Formation samples gave wide spectrum of magnetic susceptibilities ranging from moderate to high values, and Adadia Formation samples gave low to moderate paramagnetic susceptibilities. He concluded that, the magnetic susceptibility of the carbonate rocks is lower in values than those of the sandstone and clay rock samples (rich in iron oxides). He also added that, the electrical resistivity study shows that, it is affected by the uranium percentage in the studied samples, where the true resistivity decreases with the increasing of U percentage.

Mira (2003) carried out ground geophysical studies for Talet Seleim area. The intensive studies deal with detailed geological mapping, ground spectrometric, magnetic and electric (self potential "SP" and induced polarization "IP") survey. He observed that, the area of lower spectrometric levels coincides mainly with Abu Thora sandstone and the upper member of Um Bogma Formation, moderate levels were recorded over the middle member of Um Bogma Formation and the highest spectrometric levels were recognized over the middle and lower parts of Um Bogma Formation. Also, he delineated the significant radioactive provinces in Talet Seleim through identifying and outlining the significant spectrometric anomalies in the anomalously high concentrations of uranium in the areas, recognizing any possible relations between the localization of uranium mineralization and both the structure and geologic setting.

Abdel Aziz et al. (2003) applied airborne gamma-ray spectrometric measurements at Abu Zeneima – Al Tur area for monitoring the changes of environmental radioactivity or radon potentioal. They can calculate the equivalent radiation dose rate (RDR), which give the degree of hazard on the humanity and different effects in biological tissues. They also correlated the radiation radon gas (RRG) map with the surface geology of their studied area.

Rabeh, (2003) evaluated the structural set-up of the southern part of Sinai Peninsula, Gulf of Suez and western part of the Gulf of Suez from magnetic, gravity and seismic data. He showed that, the most predominant directions are the north 35°- 45° west, north 45°- 65° east, east-west and Aqaba trends.

Abdel Aziz et al. (2004) concluded that, the locations of the well known uranium, manganese and copper occurrences that can be recognized by airborne geophysical data in Abu Zeneima – Al Tur, Southwestern Sinai, have distinctive geophysical signatures.

Abd Rabo (2005) applied detail ground geophysical studies in Abu Thor area. The intensive studies deal with detailed geological mapping, ground spectrometric, magnetic and electrical survey. He found that, the strong mineralization zone supported to occur in the reduction zone.

Youssef (2006) carried out shallow seismic refraction and geoelectric resistivity sounding surveys at Wadi Al Seih-Baba area**,** Southwestern Sinai, Egypt. His study indicated that, the radioactive-bearing horizon (Um Bogma Formation) has an average thickness of about 20 m., with varying depth from 36 to 60 m. The velocity of this layer ranges between 4600 and 5000 m/s, while its resistivity varies from 40 to 300 Ω.m.

El Kattan et al. (2007) interpreted the gamma-ray spectrometric measurements which carried out on Wadi Al Seih-Baba Area, Southwestern Sinai. They proved that, the radiation levels, in general, are low compared with the surroundings, since they recorded 49 Ur, 36 ppm, 22.5 ppm, and 4.5 % as maximum values for TC, eU, eTh and K%, respectively. They found that, the radiometric levels over the geologically mapped rock units express their mineralogical composition, and the mapped radiometric anomalies are spatially correlated with Um-Bogma and Magharet Elmaiah Formations. The application of uranium migration technique showed that, the uranium is migrated out from the outcropped rock units in the area, and its migrated amounts (Um) recorded negative values with slight differentiation between the rates of migration in the rock units.

Khamies et al. (2007) analyzed and interpreted the gravity data in Al Qaa plain, Southwestern Sinai, Gulf of Suez, Egypt. They revealed that, the main structure recognized in the study area is a NW-SE sedimentary basin, which is bounded by two conspicuous uplifts, Gabal Araba to the west and the granitic massive of Southern Sinai to the east. The northwestern portion of the basin is structurally more complex and may have shallower depths than the southeastern part. The gravity data indicated that, the area can be modeled as alternative asymmetric NW-SE trending synclines and anticlines, that were faulted with a set of sub-parallel NE-SW trending linear structures. They constructed a structural gravity basement map, which showed a set of alternative NW-SE trending faults, intersected by a set of NE- SW trending faults.

CHAPTER TWO

GEOLOGIC AND STRUCTURAL SETTING

II.1. General

Sinai Peninsula covers an area of about 61,000 km^2. It is triangular in shape and is bounded by the Suez Canal and the Gulf of Suez from the west, the Gulf of Aqaba from the east, the Mediterranean Sea from the north and the Red Sea from the south.

Geomorphologically, Sinai can be divided into five units (Abdallah and Abu Khadra, 1977), as follow:

1) Southern Precambrian unit; It is made up of Pre-Cambrian igneous and metamorphic rocks forming high mountains e.g. Gabal Katherina (2641 m), Gabal Um Shumar (2586 m) and others. There are long drainage lines, such as Wadi Feiran, Wadi Ghaib, Wadi Atshan and others.
2) Tih-Egma plateau; It occupies Central Sinai and is composed of thick sandstone section at the base, overlain by marine Cretaceous and Eocene carbonates.
3) North folded geomorphic unit; This unit is characterized by NE-SW trend, composed of hilly landscape, high hill and small plateau with low stretches (Gabal Yelleg "199 m", and Gabal El-Maghara "735 m"), and separated from each other by wadi plains and wide wadis (Wadi El Buruk and Wadi Hassana).
4) Northern coastal plain; This plain extends from Rafah to Suez Canal, it is characterized by sand dunes, sand sheets, wadi sediments, sabkha sediments and Quaternary sediments.
5) Gulf of Suez coastal plain; This plain extends from Ahmed Hamdi Tunnel to Ras Mohamad. It is characterized by low relief, short wadis and made up of Cretaceous-Miocene sediments. The North Ras Millan area belongs to this coastal plain, as the area of present study.

II.2. Geologic setting of the study area

North Ras Millan area is regionally covered by rock exposures ranging in age from the Precambrian to Quaternary. A regional geologic map of Ras Millan area and its vicinities was prepared by Shata (2004). The regional rock units of the study area and the observed structures were investigated in the field (Fig. II-1). Shata (2002) prepared the stratigraphic section in the downstream of Wadi Lethi (Table II-1).

The study area is investigated geologically in details to map the exposed rock units and the structural elements (Fig. II-2), since it is covered mostly by Basement, Paleozoic and Quaternary rocks. The following is a brief description of the exposed rock units in the area, as arranged from the older to the younger:

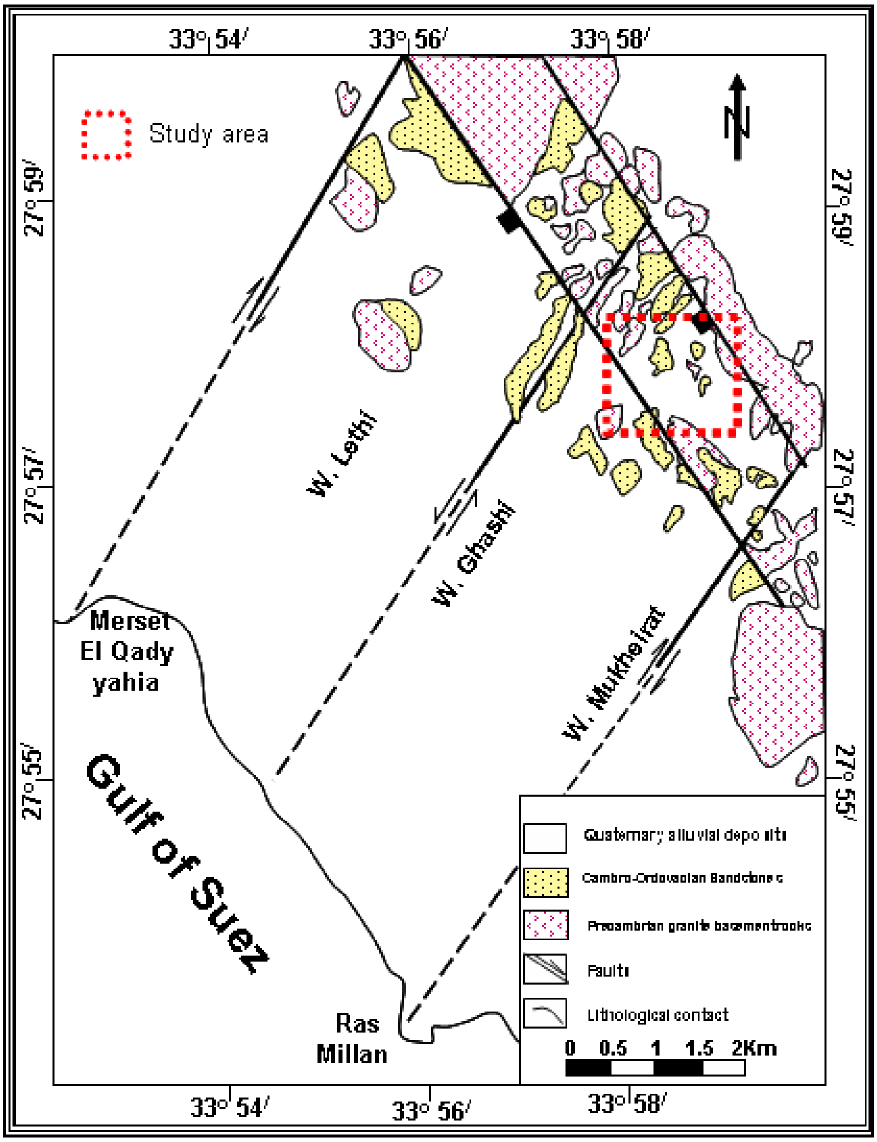

Fig. (II-1): Regional geological map of Ras Millan Area and vicinities after Shata,(2004).

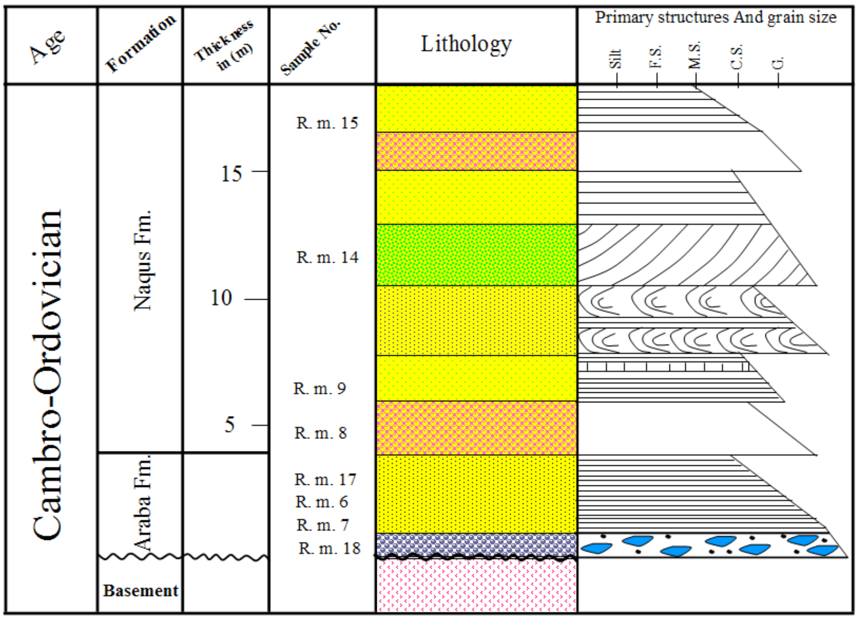

Table (II-1): Stratigraphic column in down stream of Wadi Lethi (Shata, 2002).

1) Paleozoic rocks (Araba Formation), It comprises the Cambro-Ordovician Basal Sandstone, with radioactive mineralization at its “D” Member.
2) Post-Cambrian granite, It is composed of quartz monzonite and granite, that exposed at Gabal Rigm El Wasly, Gabal El At Gharbi, Hiweimrat, downstream side of Wadi Lethi and Gabal Mezraiya.
3) Basic dykes
4) Quaternary sediments.

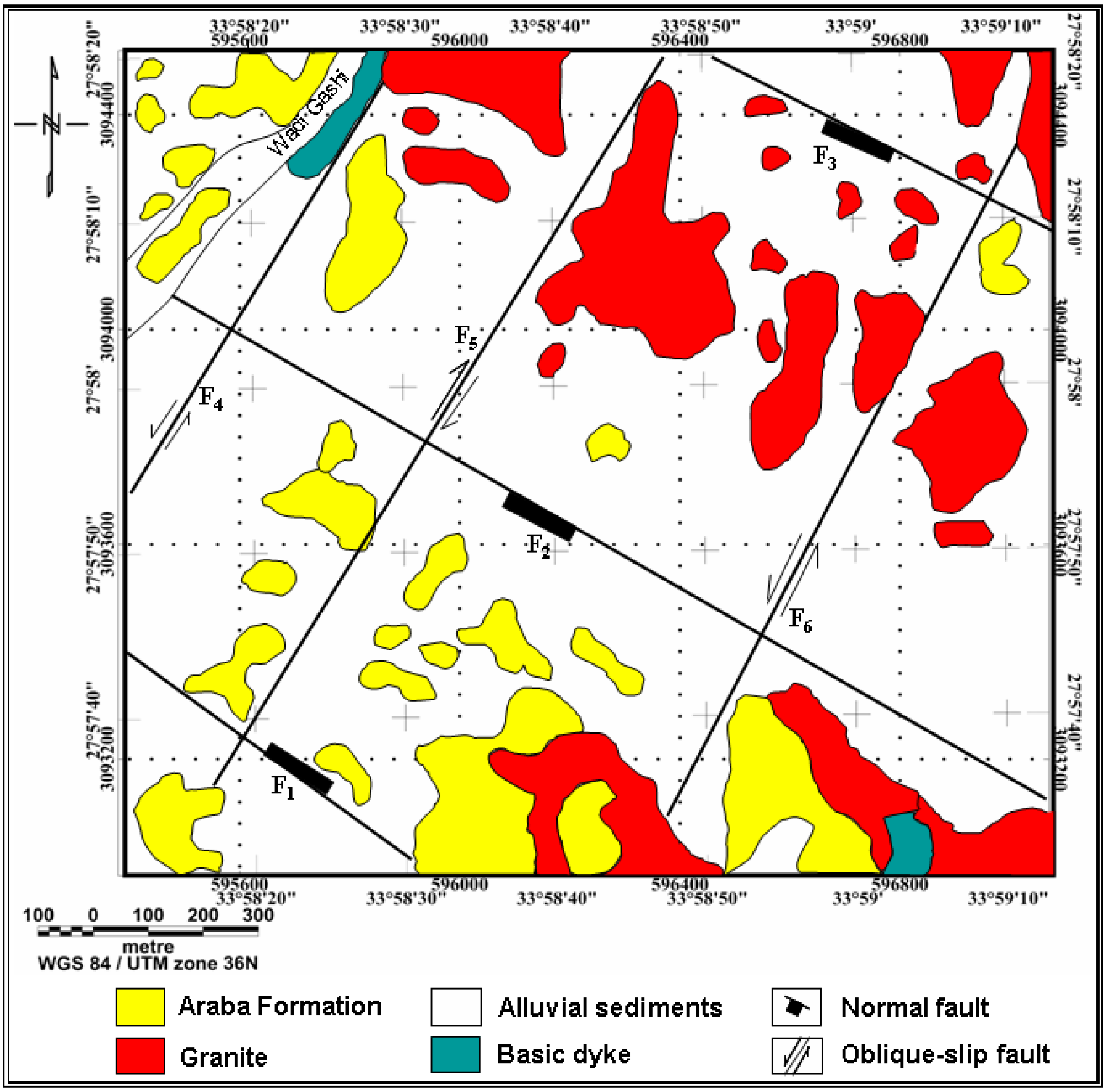

Fig. (II-2): Detailed geological map of North Ras Millan, Southern Sinai, Egypt.

II.2.1. Paleozoic rocks

II.2.1.a. Araba Formation

The Araba Formation is generally medium to coarse-grained varicolored and cross-bedded sandstone. It has a variable thickness, depending on the irregular surface over which deposition took place. The Araba Formation makes faulted belt at the foot slopes of the Precambrian Basement rocks of Southern Sinai and the lower pediment of the elevated El-Tih and El-Egma plateaux before the formation disappears below the younger sediments due to the northerly dip (Shata, 2002).

Ahmed and Osman, (1998) divided the Cambrian Formation into four clear informal units of member status (A, B, C and D Membes) in Abu Durba area. These members are easily correlatable with the Sarabit El Khadim, Abu Hamata, Nasieb and Adedia Formations of El Shahat and Kora (1986) in Um Bogma area. The Araba Formation non-conformably overlies the basement rocks, which are unexposed in the study area. Issawi and Jux (1982) used the trace fossils to assign the Basal Sandstone to Cambro-Ordovician age.

1. A Member

This member unconformably overlies the Precambrian Basement rocks and conformably underlies the B Member. Lithologically, it consists of sandstone with comparatively thin bands and lenses of conglomerate. It was first introduced by Ahmed and Osman (1998) in Abu Durba area. This member is equivalent to Sarabit El Khadim Formation, which was described by Soliman and Abu El Fetouh (1969) in Um Bogma area.

2. B Member

The Member B conformably overlies the A Member and conformably underlies the C Member. Lithologically, it is multi-colored fine-grained sandstone, siltstone and shale. It was first described by Ahmed and Osman, (1998) in Abu Durba. This unit is equivalent to Abu Hamata Formation of Soliman and Abu El Fetouh, (1969) in Um Bogma area.

3. C Member

Lithologically, this member is composed of fine grained laminated and cross-bedded sandstone alternating with siltstone and claystone beds. This member is equivalent to Nasieb Formation of El Shahat and Kora (1986) in Um Bogma area. Also, it is described by Ahmed and Osman (1998) in Abu Durba area.

4. D Member

Lithologically, this unit is composed of cross bedded and tabular planner sandstone, as well as laminated sandstone (Shata, 2002). This member is the upper part of the Araba Formation and is equivalent to the upper part of the Adedia Formation, as described by Soliman and Abu El Fetouh (1969) and El Shahat and Kora (1986) in Um

Bogma area. The age of this unit was assumed by Kora (1984), on the basis of trace fossils, as Cambro-Ordovician.

In the study area, the upper member of Araba Formation is exposed as small spots and characterized by hard sandstone with some shale and ferruginous siltstone layers. The sandstone is brown, coarse to fine grained and rounded to subangular.

II.2.2. Post-Cambrian Granite

The Post-Cambrian granites are non-conformably overlain by relatively thick clastic successions of Cambro-Ordovician age. Their rocks comprise Quartz monzogranite and granite, which are exposed in the north central, northeastern and southeastern parts of the study area. Regionally, this type of rocks is cropped out at Gabal Rigm El Wasly, Gabal Hiweimrat, Gabal Mezraiya, Gabal Khansour El Ghashi, Wadi Rabud and the downstream of Wadi Lethi, that outside the area.

The Post-Cambrian rocks intruded the dark sandstone beds of Araba Formation and raised several hundred meters high above the Araba beds. These rocks are medium to coarse-grained, hard, massive and greyish pink in color. They are fractured, highly jointed, highly weathered and dissected by dyke swarms. Issawi et. al., (1999) proved that, this type of rocks belongs to Post – Cambrian – Late Ordovician.

Due to the thermal effects of the granitic magma emplacement along their contacts with the Araba Sandstones**,** Uranium mineralizations are concentrated within the unconformity surface existed between the irregular surface of the granitoid rocks and the horizontal white Naqus Sandstones (Shata, 2002).

II.2.3. Basic dykes

These rocks are represented by Abu Gerfan Formation and Gharamoul Formation, which exposed at 3 kilometers west of Sharm El Sheikh town. This type of basic dykes is exposed and mapped in the detailed geologic map (Fig. II-2) at the northwestern and southeastern parts of the study area.

II.2.4. Quaternary rocks

These rocks are represented by wadi deposits (alluvial sediments) along the courses of wadies Lethi, Mukheirat and Rabud. They also, appear as aeolian sand sheets and dunes in the northern parts of the area (Fig.II-3).