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HOT SPOT ACTIVITY AND THEIR POSSIBLE IMPLICATIONS ON HYDROCARBON RESOURCES IN EGYPT

S.M.M. Hanafy

Nuclear Materials Authority, P. O. Box 530 El Maadi - Cairo, Egypt.

نشاطات البقع الساخنة وآثارها المحتملة على الموارد الهيدروكربونية فى مصر

الخلاصة: تعتبر البقع الساخنة هى المسئولة عن وضعية هذه الصخور القلوية فى صخور القاعدة وذلك لعمل التعديلات التكتونية وزيادة التدرج الحرارى والتى تؤدى إلى تكوين بيئة مناسبة لتركيز الخامات. ولقد تم تحديد حركة اللوح الأفريقى منذ عصر ما قبل الكمبرى من خلال تلك المسارات مع إيضاح الدليل الداعم لهذه الفكرة فيما يتعلق بآثار هذه البقع الساخنة على الوشاح السفلى و القشرة الأرضية على نمط انحراف الجيودات عن هيكل المجسم المرجعى وأيضاً الجاذبية الأرضية المقاسة من الفضاء و المنشورة حديثاً. وتعطى بيانات الارتفاعات الرقمية عالية الدقة مع صور الاستشعار عن بعد معلومات مفيدة أيضا، حيث تم تكامل كل هذه البياناتِ مع التسلسل الزمنى الجيولوجى للصخور القلوية. ويشير تأثير هذه البقع الوشاحية السفلية والتى خلالها انجرفت مصر لمدة ١٦± ٥٩٣ مليون سنة عبر اللوح الأفريقى والتى تقترح بأن البقع الساخنة هى المسئولة عن وضع الحلقيات المعقدة لمسار عصر ما قبل الكمبرى المتأخر/ الكمبرى. ويعتبر هذا المسار مثالاً ممتازاً لنوعية الحلقيات المعقدة القلوية النارية والمرتبطه باالتصدع القارى فى جميع أنحاء العالم. بالإضافة إلى ثلاثة مسارات أخرى من نشاطات البقع الساخنة فيما بعد عصر ما قبل الكمبرى فى جنوب الصحراء الشرقية والتى نوقشت من قبل. يمكن أن يكون للنشاطات النارية آثار إيجابية وأيضاً سلبية فى النظم الهيدروكربونية المحتملة. وعلى الرغم من أن الكثير من المراجع التى تدور حول هذا الموضوع تؤكدعلى هذه التأثيرات السلبية، لذلك ينبغى أن يؤخذ فى الاعتبار استراتيجية استكشافية منهجيه للهيدروكربونات التى تقع داخل وحول الصخور النارية. بالإضافة إلى أن هذه النشاطات النارية يمكن أن تنتج صخور مصدر متميزة، كاملة النضج مع ممرات مناسبة للهجرة وتكوين صخور المصايد والخزانات.

ABSTRACT: *The hot spot activity was responsible for emplacement of alkalic rocks, for tectonic adjustments and for increased geothermal gradient that created favorable ore-concentrating environments in the basement rocks. The motion of the African plate since the Precambrian times has been traced from hot spot tracks. Evidence has been put forward regarding the mantle and crustal effects of hot spot both on geoid departures from reference ellipsoid and the recently published GRACE gravity. SRTM and remote imagery data may also provide helpful information. This data integrates well with the geochronology of the anorogenic alkalic rocks dates. The effect of these mantle plumes, over which Egypt has been drifting for the past 593 ± 16 m. y. of African plate movement, suggests that the hot spot activity was responsible for emplacement the Late Precambrian / Cambrian ring complex track. This track is an excellent example of the type of composite alkaline igneous ring complexes associated with continental rifts worldwide. In addition, three tracks of Post Precambrian hot spot activity in the southeastern desert were previously discussed. Igneous activity in potential hydrocarbon systems can have both positive and negative impacts, although much of the literature on this subject has emphasized the negative influences. Hydrocarbons located in and around igneous rocks should be considered in any systematic exploration strategy. Igneous activity can produce distinctive source rock, maturation and migration pathways, traps and reservoir rocks.*

INTRODUCTION

The alkaline ring complexes in Egypt are of limited distribution and are found mainly in the Northern and Southern Eastern Desert, in addition to the southern of Sinai Peninsula which extend southwestwards into Uweinat volcanic province (Fig.1). They intrude a dominantly Proterozoic basement of gneisses, metasediments, island arc volcanics and older granitoids. They are circular to elliptical in plan, a few kilometres in diameter, and include a wide variety of granites, syenites, nepheline syenites and gabbros, as well as their volcanic equivalents, all arranged in a dominantly concentric fashion.

The Precambrian crust of the southern Sinai Peninsula is part of the northernmost sector of the Arabian-Nubian Shield. The Saint Catherine Ring Complex is a typical Late Pan-African granitoid ring complex in the Arabian–Nubian Shield.

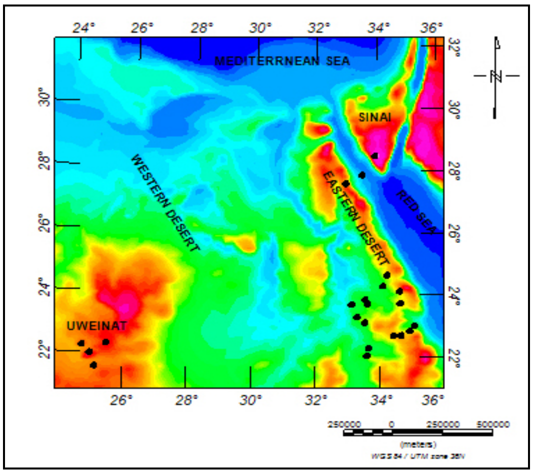

Fig. (1): Map of Egypt showing the location of some ring complexes.

Along with numerous A-type granite plutons, it was formed in the last stage of the shield evolution, when a fundamental transition in tectonic style, from compressional to extensional, occurred 620–600My ago (Gass, 1982; Stern et al., 1984; Stern, 1994; Genna et al., 2002; Meert, 2003). It is made up of syenogranite and alkali-feldspar granite. The two rock types are confined to different levels of the pluton and thus define its vertical zoning. Country rocks include a volcaniclastic suite (Rutig volcanics), a calcalkaline plutonic series represented by diorite and various granites, and a granitic gneiss. A chemical analysis of a riebechite – aegirine granite from Ras Zeit range is given by Schürmann (1964). K/Ar and Rb/Sr determinations showed a younger radiometric age than expected; rocks considerably older according to field geology, showed about the same age as the youngest plutonic intrusions, i.e. 500-550 Ma. These young ages are probably due to an early Palaeozoic rejuvenation of the Precambrian rocks (Schürmann, 1966). This corresponds with the age of the thermotectonic event (550 ± 100 Ma) which formed the Pan-African belts. The present author suggests that Ras Zeit can be discriminated as an incomplete ring structure from the false color composite ratio image (5/7, 5/4 & 3/1 of landsat ETM+ image in RGB) and needs further geological and geophysical investigations. Wadi Dib ring complex is represented by a perfect ring structure of about 2.3 km in diameter intruding a pre-existing Precambrian synorogenic granodiorites. It was thought that this is the only ring complex that is situated in the Northern Eastern Desert of Egypt. The Rb/Sr isochron and conventional ages, together with previously published K/Ar dates yielded ages that range from 593 ± 16 for Saint Catherine (Katzir, Y. et al, 2007), 582 Ma for Ras Zeit (Stern & Hedge, 1985) to 551± 11 Ma for Wadi Dib (Serencsists et al., 1979), i.e. from Late Precambrian to the Cambrian.

The study area is extended southwestwards to Uweinat area to support this work. Geologically the Gebel Uweinat is composed of two very different parts. The western part, lying entirely in Libya, is composed of a large granite ring complex, about 25 kms in diameter. As granite erodes, it forms huge boulders. The southern half is less eroded; there is a large crescent shaped plateau fills the interior of the ring, much dissected by shallow water courses. The eastern part consists of a large block of paleozoic sandstone, resting upon metamorphosed precambrian basement rocks, propped against the granite uplift to the west. Jebel Arkenu is a smaller copy of Jebel Uweinat, lying about 25 kilometres to the north-west. It is a similar smaller granite ring complex, with a broken interior drained by one main wadi system. To the northeast there is the much eroded remnant of a sandstone massif adjacent to the granite dome. Slightly further to the south is the massif of Kissu. This ring complex is very similar to those in Arkenu and Uweinat. The three igneous activities have occurred probably in the Late Eocene age from 45 to 42 ± 1 Ma. The Clayton hills are ring like craters of apparently volcanic origin, probably of similar age of Uweinat occurrence (Vail, 1976).

PREVIOUS WORKS:

El Ramly et al. (1971) stated that the distribution of the ring complexes in Egypt follows certain trends. Garson and Krs (1976) subsequently suggested that the distribution of the ring complexes in Egypt is controlled by N60°E crustal block faults and shear zones, and N30°W deep-seated tectonic zones related to the opening of the Red Sea. El Ramly and Hussein (1985), depending on the basis of their magmatic differentiation, reflected in the variety of rocks they include, and on the degree of development of the ring nature and complexity of the structure. These ring complexes are classified into the five groups (I. Abu Khruq type - II. Gezira type - II1 - Mishbeh type - IV. Mansouri type -V. Tarbtie type). Hashad and El Reedy (1979) using Rb/Sr isochron and conventional ages, together with previously published K/Ar dates suggest three phases of Post Precambrian igneous activity in Egypt which are, assigned the following ages:

The 230 ± 20 m.y. phase: during which the more saturated massif of Zargat Naam (247 m.y.), Bir Um Hebal (223 m.y.) and Silai (221 m.y.) were emplaced.

The 140 ± 15 m.y. phase: during which the more alkalic ring complex of Mishbeh (148 m.y.), El Naqa (146 m.y.), Nigrub El Tahtani (140 m.y.) and El Mansouri ((132 m.y.) were formed. The ages correspond to an early Cretaceous age and correlate well with the published ages on some alkalic ring complexes in Sudan.

The 90 ± 20 m.y. phase: during which the alkalic volcanics of Wadi Natach (104 m.y.) were erupted, followed by the intrusion of Abu Khruq (84 m.y.) and El Kafa (81 m.y.) ring complexes. The ages correspond to the late Cretaceous time.

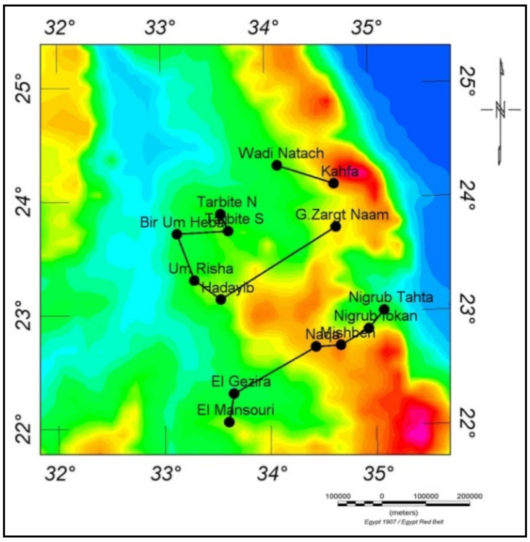

Fig. (2): Tracks of the three phases of Post Precambrian igneous activity and its ring complexes in the Southern Eastern Desert of Egypt. (Hanafy, 2012)

Kaula (1969) observed a relationship between the geoid highs and lows and the active geologic (tectonic) zones and concluded that the geoid is an expression of the deep-seated mantle movements (convection) that are responsible for geological activity. Fouad (1987) observed a striking correlation is shown between the pattern of satellite geoid departures from reference ellipsoid in Libya, attributed to inhomogeneities in the mantle, and the country's tectonic (crustal) framework.

Hanafy (2012) stated that during about 230 ± 20 m.y. of African plate motion over these (practically fixed) hot spots, Egypt has been affected by three phases of Post Precambrian igneous activity (Fig.2).

Track I hot spot (The Late Paleozoic magmatism, 230 ± 20 m.y. phase) indicates that the African plate, first rotated clockwise for about 50 m.y. in a WSW direction. Then the African plate rotation changed to counter-clockwise. He suggests that the older part of this track is related to Mount Cameroon hot spot (04° 12´, 09° 10´) Atlantic Africa. Magmatism started 230 ± 20 m.y. ago through several ring complexes (Zargat Naam, Hadayib, Um Risha Bir Um Hebal, Tarbite South and Tarbite North). This track (I) indicates that this hot spot was a relatively vigorous one.

Track II hot spot (The Late Jurassic- Early Cretaceous magmatism, 140 ± 15 m.y. Phase) is a result of the counter-clockwise drift of the African continent over a hot spot to the SSE of the one, which, produced, track I. Magmatism started 140 ± 15 m.y. ago through several ring complexes (Nigrub Tahtani, Nigrub Fogani, Mishbeh, El Naqa, El Gezira and El Mansouri). The data reveals that the ring complexes of this track may extend southwestwards into Darfur volcanic province (western Sudan). So, the study area is extended to support this idea. This track (II) indicates that this hot spot was a relatively vigorous one relative to the others.

Track III hot spot (Late Cretaceous magmatism, 90 ± 20 m.y. phase) Magmatism started 90 ± 20 m.y. ago through alkalic volcanics of Wadi Natach (104 m.y.). It erupted, followed by the intrusion of Abu Khruk (84 m.y.) and El Kahfa (81 m.y.). The geologic record of the region in Egypt suggests that the hot spot was localized and less intense in hot spot activity (Uplifting with volcanism).

DATA USED

In this research different heterogeneous data has been used: which includes high resolution 30 m (1 arc-second) NASA Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM), recently published the Gravity Recovery And Climate Experiments (GRACE) Global Geo-potential Model. The above data has been optimally combined to improve the regional gravimetric geoidal model released later. The false color composite ratio image (5/7, 5/4 & 3/1 of landsat ETM+ image in RGB) was used for the discrimination of the ring complexes exposed in the study area. This data integrates well with the geochronology of the anorogenic alkalic rocks such as Rb/Sr isochron and conventional ages, together with K/Ar dates that suggest the phase of Late Precambrian/Cambrian igneous activities in Southern Sinai and Northern Eastern Desert of Egypt. The data also reveals that the ring complexes of Saint Catherine, Ras Zeit and Wadi Dip extending southwestwards into Uweinat volcanic province (The borders of Egypt, Libya & Sudan). So, the study area is extended to support this work.

HOT SPOT ACTIVITY

Wilson (1963) suggested that the time-progressive volcanism along the Hawaiian chain could be explained by the lithosphere moving across a "jetstream of lava" situated in the mantle under the island of Hawaii. 'Hotspots' are also called midplate volcanism, and mantle plumes. Most hotspots are not 'midplate'. Hotspots occur in extensional regions of the lithosphere, either plate boundaries or intraplate (lithospheric) boundaries. Morgan (1971) estimated that some 20 hotspots were underlain by deep mantle plumes, each equivalent in strength to the hypothetical Hawaiian plume. The number of hotspots increased from the original 19–20 defined by Wilson and Morgan to 117–127 (Burke and Wilson, 1976). Courtillot et al (2003) tabulated the characteristics of 49 'hotspots' and compared them with a list of plume criteria. Courtillot lists included About 7 in Africa (Table 1).

Ring complexes in landsat etm + imagery:

The false color composite ratio image (5/7, 5/4 & 3/1 of landsat ETM+ image in RGB) was used for the discrimination and mapping of some ring complexes exposed in the study area (Figs 3, 4, 5 and 6). Using the theoretical knowledge about the spectral properties of most rocks and minerals, ETM+ bands 3/1 and 5/7 were selected for iron oxides and hydroxyl bearing minerals respectively, whereas band ratio 5/4 has been computed to enhance possible ferrous oxides. Drury and Hunt (1989) denoted that the ETM+ bands 1 to 4 contain information on iron minerals. The mapped ring complexes are namely: Saint Catherine, Ras Zeit, Wadi Dib, Jebel Uweinat, Jebel Arkenu, Jebel Kissu and the Clayton craters. These ring complexes can be divided into distinct types formed at different times and crustal levels. The volcanic highlands and flanks of the ring complexes are represented as reddish brown color, where this darkness color is due to high absorption of electromagnetic waves, and have oval or circular shape, sharp ridges, high relief and sharp contacts with the surrounding rocks. The central pluton younger granites show green to light green toned color due to medium reflectance and absorption.

Srtm and grace gravity signatures:

The topographic features of the southern Sinai are very different from those of the Northern Eastern Desert of Egypt (Fig. 7). The Saint Catherine Complex is situated in the high mountainous area of the Sinai Peninsula. Gebel Mussa, the mountain in the central part of the Complex, is traditionally believed to be the biblical Mount Sinai. The total area of the Complex is over 400 km^2. Meanwhile, Ras Zeit and Wadi Dib area is characterized by its mild topography. The area is highly dissected by several longitudinal and transverse dry valleys mainly draining towards the Gulf of Suez.

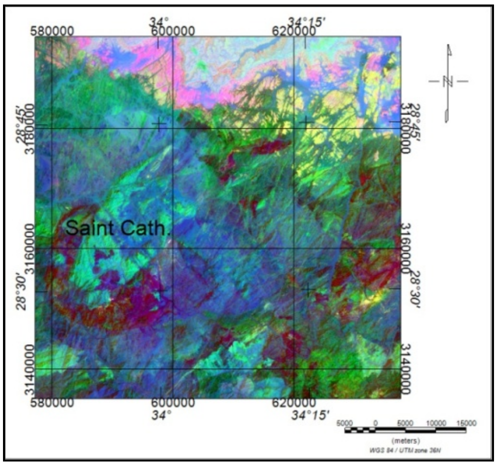

Fig. (3) False color composite ratio image (5/7, 5/4, 3/1 in RGB) of Saint Catherine ring complex.

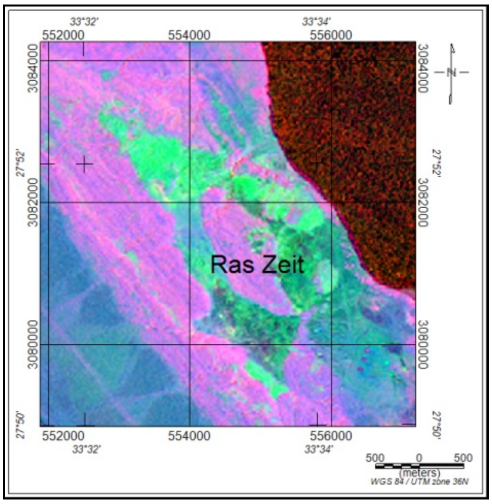

Fig. (4) False color composite ratio image (5/7, 5/4, 3/1 in RGB) of Ras Zeit ring complex.

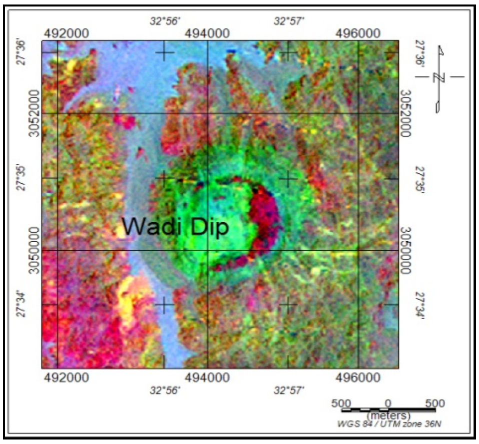

Fig. (5) False color composite ratio image (5/7, 5/4, 3/1 in RGB) of Wadi Dip ring complex.

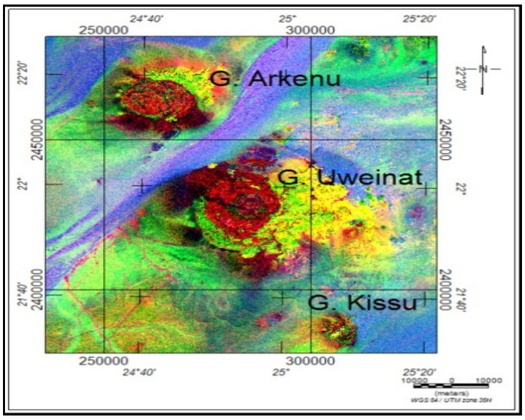

Fig. (6) False color composite ratio image (5/7, 5/4, 3/1 in RGB) of the three ring complexes of Uwienat volcanic province.

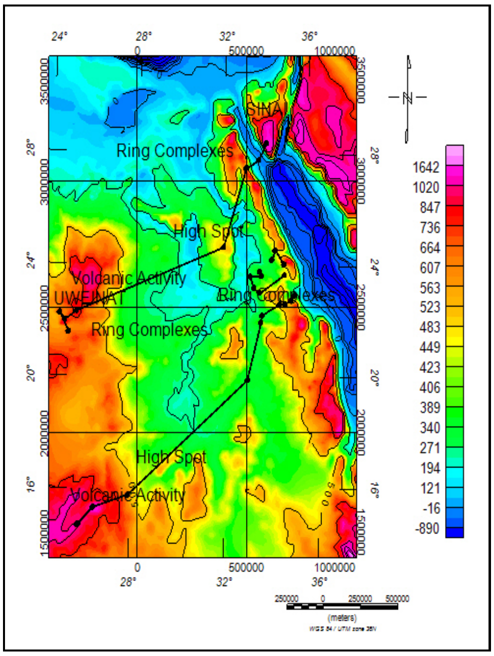

Fig. (7): SRTM Digital Elevation Model map of the study area.

The alkaline rocks are of limited distribution in the Southwestern Desert of Egypt and are represented mainly by some ring complexes, ring dykes, plugs and volcanic flows. Gebel Uweinat is the most formidable mountain in the generally flat and featureless Egyptian / Libyan Desert. Situated roughly at the centre of the aridest area, it stands out like an island from the surrounding plain. The plain between Uweinat and the Gilf Kebir is dotted with groups of low hills that from a distance resemble the other flat topped masses of the region.

Large-scale gravity anomalies can be detected from space. Gravity data derived from GRACE satellite Mission indicate different gravity signatures, igneous complexes of dominant acid composition are characterized by low gravity values and those of dominant basic lithology are indicated by positive gravity signature. Using gravity data, widespread intrusive and extrusive bodies within the basins have been mapped (Fig. 8). Numerous sills, dykes, volcanic cones and lava flows are spectacularly imaged in gravity data, showing a range of morphologies. The buried igneous bodies typically display high amplitude positive gravity responses due to great density contrasts with the surrounding country rock. These igneous rocks are hereafter referred to as high spot activity.

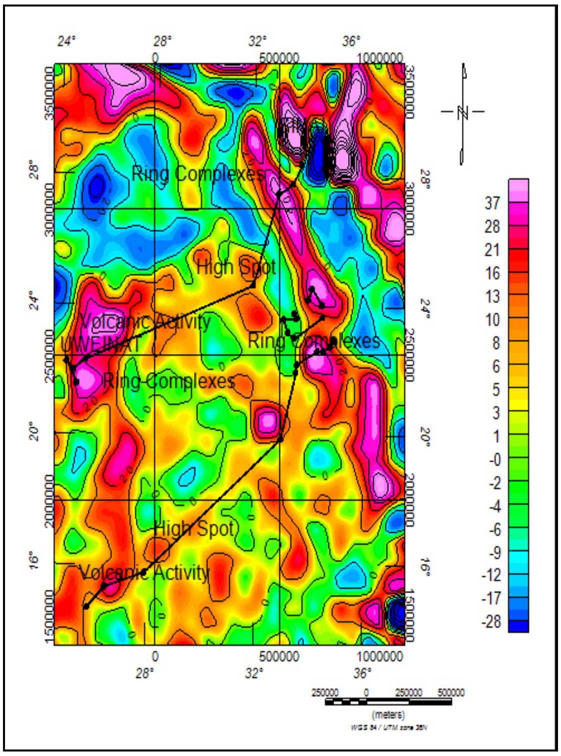

Fig. (8): GRACE gravity map of the study area.

GEOID DEPARTURE:

The geoid relief is a combination of the usual effects of the anomalous heterogeneity of the lower mantle and the superimposed upper mantle ones. Thus the geoid relief contours, measuring its departure from the reference ellipsoid, along the hot spot tracks of Egypt were shown to indicate the relative intensities of these hot spots and their possible effect on the geologic evolution of the basement and volcanic areas. A variation of more than 20 m in the geoid relief is the first striking feature on such a relatively small area of the world. The most prominent parts of the geoid are those at the northeastern and the northwestern regions of the area. Away from this high, the geoid relief flattens out relatively steeply southeastwards. The striking correlation observed between the geoid relief pattern and the hot spot tracks affecting the area (Fig. 9) shows how the mantle plume tracks are neatly aligned with the geoid relief contours, whose correlation with the tectonic framework can also be readily recognized; the following are examples:

- The Late Precambrian/ Cambrian uplifting encompasses most of the ring complexes of the Saint Catherine, Ras Zeit , Wadi Dib correspond with a characteristic nosing of high relief geoid departure in the NW of the area.
- The Late Eocene uplifting encompassing most of the ring complexes of Uweinat, Arkenu and Kissu corresponds with the near circular high relief geoid closure in the SW of the area.
- The area in between, show a circular pattern of geoid relief contours closely corresponds with the structure trends in the area (Forced folding of overlying strata by high spot igneous activity).
- The SE corner of Uwienat volcanic province is manifested on the geoid relief map by correspondingly oriented contours, which likewise plunge relatively steeply southeastward into the south of Sudan.

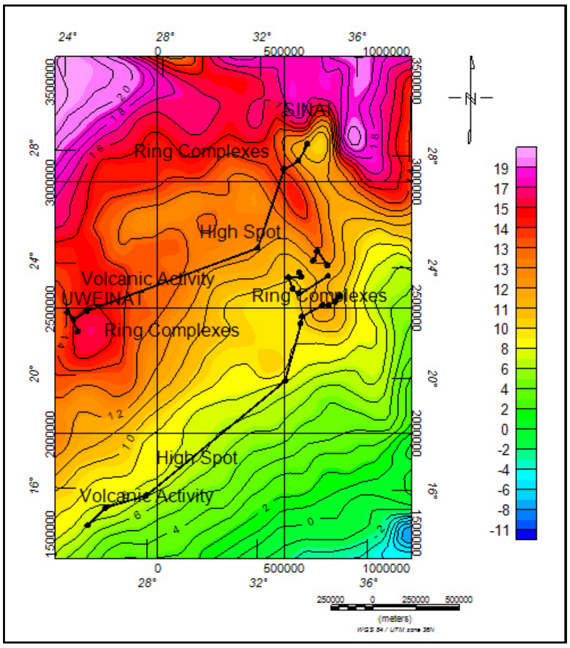

Fig. (9): Departure of the geoid from reference ellipsoid map of the study area.

IMPLICATIONS FOR HYDROCARBON RESOURCES

Volcanic and intrusive bodies in Egypt have occurred during most of its geological history. Numerous sills, dykes, volcanic cones and lava flows are spectacularly imaged in gravity data, showing a range of morphologies. During Mesozoic time frequent volcanic activity is recorded in Late Cretaceous formations and related to the early phases of crustal disturbances during the Laramide orogenic phase. Triassic and Jurassic intrusive and extrusive are present in Sinai, the Eastern and Western deserts. Tertiary volcanics in the form of basalt flows, sheets and dykes occur in the western desert, in the Nile valley and Nile Delta. Oligocene basalt dykes have been reported in some Miocene formations in the Gulf of Suez (Said, 1962).

Table (1): List of hot spots in Africa (After Courtillot et al, 2003)

No.	Name	Location Lat. - Lon.	Type	Tectonics	Country
1	Afar	12° 00´- 42° 00´	Triple Junction	T3	Ethiopia
2	Cape Verde	15°00´- 24°00´		Edge	Off NW Africa
3	Hoggar Mountains	23° 00´- 06° 00´			Algeria
4	Jebel Marra, Darfur	12° 57´- 24° 16´	Movable Plate	FZ	Sudan
5	Lake Victoria	-03° 00´- 36° 00´			East Africa
6	Mount Cameron	04° 12´- 09° 10´	Movable Plate	FZ	Atlantic Africa
7	Tibesti	21° 00 -´ 17° 00´	Movable Plate	FZ	Chad

T3 = Triple Junction FZ = Fracture Zone

Table (2): the hot spot track of the Late Precambrian/ Cambrian with the geochronology of the anorogenic alkalic rocks.

No.	Ring Name	Location		Type	Age		Country	Track	Ref.
		Lat.	Lon.		Era (Period)	M. y.			No.
1	Saint Catherine	28° 30´	34° 54´	Alkaline Volcanics & Ring Complexes	Late Precambrian/ Cambrian	593 ± 16	Egypt.	Pre - I	1
2	Ras Zeit	27° 53´	33° 29´			582 Ma			2
3	Wadi Dip	27° 35´	32° 56´			551± 11			3
• The manifestations and intensity of the plume changed and less intense. • The activity limited to epeirogenic uplift. • Magmatism recurrent towards the Southwest of Egypt.					Early Paleozoic	490 Ma to 49 Ma			
					Mesozoic				
					Early Cenozoic				
4	Clayton's Craters	22° 20´	25° 30´	Alkaline Volcanics & Ring Complexes	(Tertiary) Late Eocene	45-42 ± 1	The borders of Egypt, Libya & Sudan		4
5	G. Arkenu	22° 15´	24° 45´						
6	G. Uweinat	22° 00´	25° 00´						
7	G. Kissu	21° 35´	25° 10´						
References: (1) Katzir, Y. et al (2007). (2) Stern & Hedge (1985). (3) Serencites, et al (1979). (4) Vail (1976).					Methods Potassium – Argon (K - Ar) Rubidium - Strontium (Rb - Sr)				

Igneous activity in potential hydrocarbon systems can have both positive and negative impacts (Schutter, 2003a), although much of the literature on this subject has emphasized the negative influences. The effects of magmatism on hydrocarbon systems can be grouped into three broad categories: heating and maturity, reservoirs and seals, and trap formation.

Evolution and the hydrocarbon bearing capacity of basins are closely related to volcanic activity, and not only source rock maturity, but also hydrocarbon trapping are influenced by volcanism within a basin. Volcanic rocks act as important basin filling material in different types of basins, for instance, rift basins, epicontinental basins, basins in a trench-arc system, back-arc foreland basins, etc.

Three distinct oil provinces, the Gulf of Suez, the Western Desert and the Nile Delta, contribute to this wealth of hydrocarbons (Fig. 10). The largest part of the production and reserves derives from the Gulf of Suez. Each of these provinces has its own geological history and structural characteristics. Other potential oil provinces are believed to exist in presently untested areas of Wadi Kharit in the Southern Eastern Desert and the area located in the East Uweinat basin. The occurrences of ring complexes and volcanic activity of the Late Paleozoic magmatism (Track I) are largely confined to Wadi Kharit and Wadi Jararah basins.

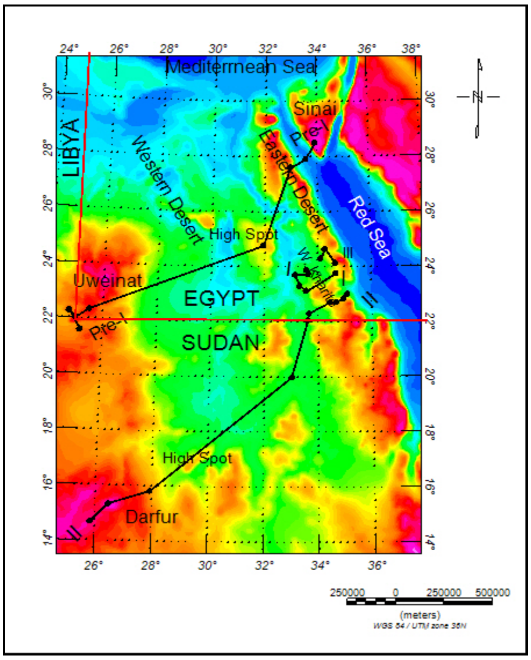

Fig. (10): Tracks of the four phases of the Late and Post Precambrian igneous activity of the study area.

The westernmost part of the central East Uweinat basin, contains the greatest density of igneous occurrences and the majority of ring complexes (end of track Pre-I). So, much of the work on the implications of igneous activity on hydrocarbon systems should be focused on the potential overmaturity risk posed by the heat input of these bodies. Schutter (2003a) suggested that evaluation of potentially commercial hydrocarbon accumulations requires interpretation of well logs, which may have unusual characteristics. Drill stem and production tests may also be needed for evaluation before exploration ends and development begins.

DISCUSSION

The analysis of the hot spot tracks reveals some important aspects, which are of significance to the present work. It is important to note that a plate motion is a rotation, and so the tracks approximate concentric circles rather than parallel straight lines. During about 593 ± 16 m.y. of African plate motion over these (practically fixed) hot spots, Egypt has been affected by four of them. The discussion is hereafter referred to the oldest track in Egypt and its implications on hydrocarbon resources (Table. 2 & Figs 7 to10). The other three tracks of Post Precambrian hot spot activity in the southeastern desert were discussed earlier by Hanafy (2012).

Track Pre-I hot spot (The Late Precambrian/ Cambrian, 593 ± 16 m.y. phase) is a result of the counter-clockwise drift of the African continent over a hot spot with a suggestion that the older part of this track is related to Tibesti hot spot in Chad (21° 00 -´ 17° 00´), where, magmatism started 593 ± 16 m.y. ago through three ring complexes (Saint Catherine, Ras Zeit and Wadi Dib). The Late Precambrian magmatism in the midcontinent was regional and intense; large volumes of alkaline silicic magma were transferred into the upper crust. The mantle pluming my extent through a long period of geologic time and its manifestation and intensity may change. The discharge rate of a plume may also vary over time even in the same track. The geophysical data indicates that the postulated Mesozoic hot spot activity did not reach an advanced rifting stage, and is associated with positive gravity anomaly. The activity is limited to epeirogenic uplift (Al Kharjah Oasis). The high relief geoid departure along a mantle plume track coincides with pronounced geologic and/or tectonic activity (Granitic ring complexes exposure and volcanic eruptions of Late Eocene), where magmatism recurrent with high intensity towards the Southwest of Egypt. It started 45 ± 1 m.y. ago through three ring complexes (Uweinat, Arkenu and Kissu) and the Clayton ring like craters. This is the most prominent track of Africa and indicates that this hot spot was a relatively vigorous one. The parallelism and synchronolization of this track with that track of the Late Jurassic- Early Cretaceous magmatism (II) was noted and suggested that this track was controlled by crustal flow aligned with the northeast trending regional geoid departure from ellipsoid (Fig. 9). It is also suggested that magmatism started in track (II) 587 ± 8 m.y. ago through Silsilah ring complex in the Kingdom of Saudi Arabia (26° 06 -´ 42° 40´).

Using the new information obtained in this study, the timing of magmatism has important implications for the hydrocarbon potentiality in the Western Desert petroleum province, specifically in relation to maturation, trap formation and trap integrity. Hydrocarbon production is concentrated almost exclusively in Cretaceous carbonate and clastic reservoirs, with the exception of some oil fields which also produce from the Late Jurassic. In order to achieve this, an accurate constraint on the timing of magmatism is required. Through Mesozoic time, a continental depositional environment prevailed over the whole of the Western Desert. There, Precambrian basement and/or Paleozoic clastic series are unconformabley overlain by the Nubia strata, whose age ranges from Jurassic to Late Cretaceous. Although isotopic dating is lacking for the high spot activity of the Western Desert, a constrained interval of time can be derived using geophysical data and relative dating techniques. Previously, based on the interpretation of regional-scale gravity and geoid datasets, it was not possible to determine the exact age of the igneous activity, and it was believed to be to be either Late Mesozoic to Early Cenozoic where as the high spot activity in the Western

Desert was short-lived. The influence of these rocks on petroleum systems is uncertain at this stage; however, evidence from other regions suggests that the negative impact will be minimal unless the magmas made direct contact with the existing hydrocarbon accumulations. A more important concern is the potential effect a postulated magma reservoir at depth will have on burial history scenarios and petroleum systems modelling for the Western Desert Basin.

CONCLUSIONS

The hot spot activity was responsible for emplacement of alkalic rocks. The effect of these mantle plumes, over which Egypt has been drifting for the past 593 ± 16 m. y. of African plate movement, suggests that the hot spot activity was responsible for emplacement the Late Precambrian / Cambrian ring complexes. In addition, three tracks of Post Precambrian hot spot activity in the southeastern desert previously discussed. Igneous activity in potential hydrocarbon systems can have both positive and negative impacts. Three distinct oil provinces, the Gulf of Suez, the Western Desert and the Nile Delta, contribute to this wealth of hydrocarbons. Other potential oil provinces are believed to exist in presently untested areas of Wadi Kharit in the South Eastern Desert and the area located in the East Uweinat basin. The occurrences of ring complexes and volcanic activity are largely confined to these two areas. Hydrocarbons located in and around igneous rocks should be considered in any systematic exploration strategy. The timing of magmatism has important implications for the hydrocarbon potentiality in the Western Desert petroleum province, specifically in relation to maturation, trap formation and trap integrity. The Late Mesozoic to Early Cenozoic high spot activity in the Western Desert was short-lived. The influence of these rocks on petroleum systems is uncertain at this stage; however, evidence from other regions suggests that the negative impact will be minimal unless the magmas have come into direct contact with existing hydrocarbon accumulations.

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