Potential Uranium Provinces in Some Arabian Countries

Abdel Aty Salman
Nuclear Materials Authority, P.O. Box 530, EL Maadi, Cairo -, EGYPT.

خلاصة

تمثل هذه الدراسة محاولة لتحديد مكامن اليورانيوم المحتملة في بعض الدول العربية وقد استندت هذه الدراسة على الوضع الجيولوجي والتكتوني بالإضافة إلى التتابع الزمني وبعض الخواص الجيوكيميائية .

ومن الجدير بالذكر أن هذه المحاولة سوف يكون لها عظيم الأثر في تبادل الأفكار والمعلومات الجيولوجية التي سوف تساعد في تطوير صناعة اليورانيوم في الوطن العربي .

ونتيجة لهذه الدراسة أمكن التوصية والتنويه عن احتمالات وجود عدد من مكامن اليورانيوم في بعض الدول العربية .

Abstract

This work represents an attempt to delineate potential uranium provinces in some Arabian countries using various related recognition criteria. Definition of these provinces is based on the available geologic and tectonic setting beside geochronological sequence and some geochemical characterestics. This trial would be of a great help for interchanging the ideas and necessary data for the development in the fields of uranium exploration and production. As a result of this study, a number of promising potential uranium provinces are recommended in some Arabian countries.

1. Introduction

The present study contains three main parts. The first one includes an introduction about the various types of uranium deposits and their favourable geologic environments, and uranium exploration techniques. The second part includes a summary of some recognition criteria for the identification of uranium provinces especially in granitoids and sandstone formation. The third part represents the potential uranium provinces in some Arabian countries; namely: Egypt, Libya, Saudi Arabia and Sudan.

1-1. Principal Uranium Deposits

The first and fundamental step in any uranium exploration programme is the development of an integrated geologic and geochemical analysis and understanding of the genesis of the potential uranium accumulations under investigation. The bulk of the world's uranium, has been produced historically from(1)lower Proterozoic uraninite placer deposits in quartz-pebble conglomerates, (2) epigenetic uranium deposits in sandstones located in many cases[1] at, or near, groundwater oxidation-reduction interfaces and (3) hydrothermal vein uranium deposits. Exploration for economic uranium deposits has expanded to many geologic environments that have been generally overlooked in the past. Most notable among these are (1) granitic uranium deposits. (2) alkalic igneous-hydrothermal uranium deposits. (3) altered acidic or alkalic volcanic ash, ash flow or volcaniclastic uranium deposits. (4) unconformity-related uranium deposits and (5) calcrete uranium deposits in desert groundwater environments.

1-2. Uranium Exploration Techniques

Exploration techniques are generally reviewed or tabulated according to discipline. They start from reconnaissance programmes to more local or detailed programmes [2].

1-2-1. Reconnaissance exploration techniques

Exploration techniques of widespread use in reconnaissance uranium exploration programmes include (1) geologic mapping, basin analysis and search for favourable geologic environments, (2) remote-sensing data analysis and synthesis. (3) gamma ray spectrometry (airborne and ground) and (4) hydro- geochemical and lake sediment sampling. Depending on the nature and scope of the exploration programme,the above-described reconnaissance steps are often conducted simultaneously in a first phase of exploration and their results are integrated and analysed to select local favourable areas for more detailed exploration techniques in a second phase of exploration.

1-2-2. Detailed exploration techniques

Detailed exploration techniques are applied generally on favourable target areas that have been delineated by the reconnaissance or more regional exploration techniques. Exploration techniques used commonly in various combinations in local or detailed programmes include(1) detailed geologic and alteration mapping,(2) detailed hydrogeochemical surveys,(3) detailed radiometric surveys,(4) radon and helium soil-gas surveys,(5) soil and rockgeochemical surveys,(6) subsurface stratigraphic analysis,(7) non-radiometric geophysical surveys,(8) geobotany and biogeochemistry (9) exploration drilling and logging and exploratory tunneling.

The geology of the area of detailed exploration and the nature of the potentially favourable geologic environments determine the relative utility and sequence of use of these and other detailed exploration techniques.

2. Recognition Criteria for Uranium Provinces

The recognition criteria for identification of uranium provinces depends upon the characteristics of the host rocks and the associated type of uranium deposits. The present work will concentrate upon the recognition criteria for granitoids and sandstones uranium provinces. These criteria will be utilized for recommending potential uranium provinces in some Arabian countries.

The recognition criteria for identification of uranium provinces in granitoides mainly include uranium contents, formation ages and lithology. The average uranium contents in various types of granitoids should be thourally determined. This is rather important to deferentiate between the uranium enriched and normal granites. In Brazil, the average uranium content in normal granites is about 3 to 7 ppm, they considered the 12 ppm uranium as a limit between uranium-enriched and normal granites[3]. It is found that uranium contents are 5 to 10 ppm and thorium contents are of 15 to 25 ppm in samples from one enriched granite pluton of Pan-African Shield, thus yielding Th/U ratios of 2 to 2.5[4]. The low Th/U ratios of granites are interesting in view of the fact that most highly differentiated granites have Th/U ratios greater than 4. Such low ratios could either result from thorium loss from the granites, which is geochemically unlikely, or uranium addition to the plutons. The low ratios also make it unlikely that uranium in the wall rocks around the mineralized plutons could have formed from hydrothermal fluids obtained from the plutons themselves, a process that should have increased the Th/U ratios in the remaining (source) granite to high values.

The relation between uranium enriched granitoids and geological-time- bound is of remarkable importance, because it is known that some uranium enriched granitoids are restricted to certain ages. For example, it is found that uranium enriched granitoids are strongly related to 1800- 1300 Ma time interval. However, some high frequences for uranium enriched granitoids are noticed at the time interval of 2600-2000 Ma, 2200-1800 Ma and 900-500 Ma [3].

It is evident that the uranium contents distribution are related to different granitic lithological groups. The granitoids with granitic compositions and the alkaline granites present higher uranium concentrations. In general the U-enriched alkaline granitoids are mainly composed of syenites and quartz-syenites and the granites are constituted by biotite-hornblende granites. Also, the granite related uranium veins occur inside or outside late magmatically or metamorphically altered peraluminous leucogranite [5]. The study of the initial Sr ratios is rather important, where it can be utilized in the determination of the source of U-enriched granitoids.

The recognition criteria for identification of uranium provinces in sandstones varies according to the type of the deposit [5]. Uranium as disseminations in domenantly continental fluvial arkosic sandstone, commonly interbedded with argillaceous horizons, and almost flat lying ($< 5^{o}$) unless post-oretilted; frequently associated with tuffaceous sediments. A distinction is made between (a) Phanerozoic (Post Devorian) deposits associated with terrestrial plant derived organics and (b) Proterozoic deposits associated with algae derived volcanics [4].

In the roll front, two classes are present, continental basin and coast plain. In the continental basin U as disseminations at redox boundary in arkosic and subarkosic sandstones deposited in intracratonic or intermontane basins, spatial proximity to rocks containing anomalous U concentrations such as tuffs or granites essential. Most deposits occur within interbedded sequences of fluvial sandstones and volcanic rich sediments without major time or erosional breaks.

3. Potential Uranium Provinces:

3-1 .Egypt:

Egypt is covered with various rock exposures which include

Precambrian basement and thick sedimentary cover. The Precambrian basement rocks cover about 100,000 sq. km in south Sinai, Eastern Desert and limited exposures in the south Western Desert. The basement rocks are grouped into; Pre-Pan-African rocks, comprising higher grade metamorphic rocks and Pan-African rock assemblage, comprising ophiolites and the island arc association, a tectogenetic rock association and Phanerozoic alkaline rocks [6].

The thick sedimentary sequence includes various rock types ranging in age from Paleozoic to recent. The lower part of this sequence is mainly composed of continental clastics with some marine ossilations and then grading upward to carbonate and fine clastic association. The upper part is mainly composed of clastics with some evaporites and some marine ossilations.

Uranium exploration started in Egypt since 1956. This was performed by applying integrated airborne and ground radiometric prospection. These activities led to the discovery of several radiometric anomalies and uranium occurrences in various geologic environments. The most promising uranium occurrences are localized in the younger postorogenic granites, and Paleozoic clastic sediments. By reviewing the various criteria recognized in the different uranium occurrences in Egypt, the following potential uranium provinces are of remarkable importance.

3-1.1 Granitoid Uranium Provinces:

Many of the post tectonic younger granites in the Egyptian region are of the uraniferous type, where normal uranium content ranges from 10 to 35ppm[7],[8] and [9]. The following granite plutons can be considered as potential uranium provinces.

Gebel Qattar: In Gebel Qattar (Fig.1) the uranium mineralization is mainly hosted in younger biotite granite. This granite is essentially composed of quartz, orthoclase with subordinate oligoclase and biotite. The accessory minerals are represented by hematite, zircon, sphene and apatite. The uranium mineralization is associated with fault zones and small scale fractures which follows NNE, ENE and NWdirections, where the mineralization is present in a patchy form [10]. The associated alteration features are represented by intense hematitization, partial kaolinization, light carbonitization and deep violet fluorite is frequently present [10]. The identified secondary uranium minerals are: uranophane, carnotite, clarkeite, kasolite, zippeite, soddyite and primary uraninite [11].

El Missikat: The uranium mineralization is hosted in ENE trending shear zones within orthoclase granite. It connected with jasperoid silica [12] and strong alteration represented by silicification, sericitization, hematitization and kaolinization. The uranium minerals are mainly uranophane and soddyite with finely disseminated sooty pitchblende. They are accompanied with sulphide and gangue minerals. Sulphides are mainly: pyrite, calcopyrite, galena, sphalerite and molybdenite. The gangues are mainly iron and manganese oxides and fluorite [13].

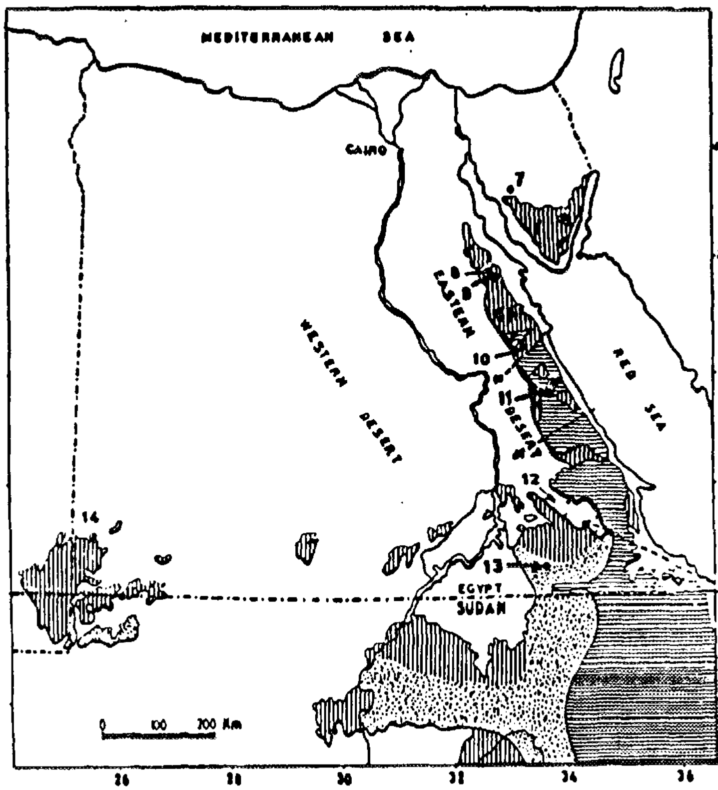
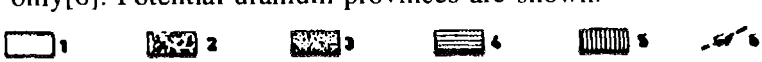


Fig. 1 : Distribution of precambrian rocks in Egypt and Northern Sudan rocks of archean age are confirmed in the western desert only[6]. Potential uranium provinces are shown.



1= Phanerozoic, 2= Hammamat Clast. & Dokan Volcanics, 3= Foreland Assoc., 4= Late proterozoic Ophiolites and island arc volcanics & volcaniclastics, 5= Archean and Early proterozoic rocks, 6= Inferred major shear.

Potential uranium provinces: 7= Um Bogma, 8= Um Tawat Hammamat, 9= Gebel Qattar granite, 10= El Missikat and El Erediya, 11= South Wadi El Kareim Hammamat, 12= Wadi Um Kharit, 13= Um Ara, 14= G. Al Uwaynat.

El-Erediya: El-Erediya pluton was emplaced during the post-tectonic episode in Egypt, 603-575 Ma [14]. It is emplaced near the northern edge of the central tectonic block of the Eastern Desert, which dominantly exposes rock swith strong oceanic affinity [15] and [16]. The granitic rocks of El Erediya pluton are essentially composed of potash feldspars, plagioclase and quartz, with subordinate biotite. Zircon, sphene, apatite and magnetite are present as accessory minerals [17]. In El-Eradiya-1 uranium occurrence uraninite, uranophane, B-uranophane, soddyite and renardite are the main uranium minerals [18]. The mineralization is associated with red jasper, black and grey amorphous silica, chalcedony and quartz. Gangue minerals are represented by quartz, carbonate and fluorite.

Um Ara-Um Shilman: Radioactive mineralizations in Um Ara - Um Shilman younger granite pluton are restricted to the medium grained variety which range in composition from albitized to the potash feldspar-rich granites. Uraninite and/or thorite inclusion in orthoclase, plagioclase feldspars, quartz and biotite which points out to their syngenetic origin. Later alteration caused their oxidation to a group of secondary minerals including uranophane and curite [19]. These minerals are associated with deep violet fluorite. The wall rock alteration comprises silicification, microclinization, albitization and hematitization. The uranium mineralization of Um Ara are structurally controlled following WNW and NW trends [20].

It is noteworthy to say that the above mentioned granite plutons are of high potentiality for identification of workable uranium deposits which belong to vein type. In spite of the high clark of uranium values in these postorogenic PanAfrican granites there is no potentiality for finding a large concentration of magmatic uranium. This was indicated from the study of the geochemical behaviour of the REE and some other trace elements in the analyzed samples from El-Erediya granite and the associated uranium mineralization [9]. Moreover, Struckless, et al., [21] found that the low Th/U ratios and high U/K ratios argue against any concentrating of uranium by magmatic processes in the post orogenic granites of the Northwestern Arabian Shield. However, there is a high potentiality for identification of uranium deposits in the discussed uranium granitoid provinces in the Eastern Desert of Egypt. The hydrothermal vein type uranium deposits of low to medium scale could be identified in the marginal zones of these granite plutons. This prediction is based upon the attained results of the exploration works and the presence of various types of uranium occurrences [22]. The persistance of the secondary uranium mineralization for more than 300m from the surface, increasing of gapping of the shear zones with depth, existance of strong hematitization, partial silicification and fluoritization and the presence of a pitchblende in some underground works are encouraging results.

3-1.2. Hammamat Basins

These intermontane basins include molase-type poorly sorted clastic sediments, intercalated with minor impure calcareous layers [6]. They are best developed in the northern part of the central Eastern Desert and attain substantial development in the north Eastern Desert and Sinai. From uranium potentiality point of view two Hammamat provinces in the Eastern Desert could be considered as exploration targets. They are located south of Wadi El Kareim and Gebel Um Tawat (Fig. 1). The south Wadi El Kareim province is present in the form of an oval shape basin with an axial trace following ENE to WNW trend. The north margin is partly dislocated by a thrust fault following ENE [23]. The importance of this province is concentrated in the presence of a huge igneous activity within it. This igneous activity is represented by numerous bostonite dykes, sills, plugs. These bostonites are present in three generations, two of them include radioactive anomalies and uranium mineralization [23]. Moreover, this province is nearly surrounded with numerous post orogenic uraniferous younger granite plutons. This environment is rather suitable for the formation of uranium.

Gebel Um Tawat province is located in the north Eastern Desert to the west of Hurghada City (Red Sea) by about 50 km. It is represented by a thick succession of the Hammamat sediments forming an intermontane basin. These sediments are underlained with post orogenic younger granites which are occasionally exposed on the surface. The southern zone of this province is occupied by Gebel Qattar uraniferous granite. Secondary uranium mineralizations are detected within the Hammamat sediments at the contact zone with G. Qattar granite. Along this zone strong hydrothermal alterations are recorded. Hematitization, kaolinization, carbonitization, silicification, epyseynitization and fluoritization are frequently noticed [22]. Moreover, some secondary uranium mineralizations are noticed within the epyseynitized granite in this occurrence. Accordingly, these features often supports uranium potentiality in this province. It needs an application of detailed ground geophysical exploration to delineate the configuration, structural framework, alteration zones including sulphide bodies of this province.

3-1.3. Paleozoic Provinces

The Paleozoic exposures in Egypt are relatively of limited distribution. They are outcroped surrounding some Precambrian basement rocks in the south western Desert, Eastern Desert and Sinai. By reviewing the available information about uranium distribution in the Paleozoic rocks of Egypt, the following Paleozoic provinces could be considered as good targets for uranium exploration.

Gebel Al Uwaynat Province: The Paleozoic strata in this province are located between G. Al Uwaynate and the Abu Ras Plateau west of Gilf Kebir. There are strata of ordovician, Silurian, Devonian, Carboniferous and Permian to Triassic age of combined thickness of up to 1000m thickness are present at the eastern edge of Al Kufra Basin and the south west of Dakhla Basin [24]. In this province, El Aassy [25 and 26] recorded some radioactive anomalies and high uranium and/orthorium content in some Paleozoic units. It is important to mention that uranium anomalies were discovered in the Silurian Tanezzuft, Devonian ouan Kasa, Carboniferous Assedjefar and Dembaba, and in the Zarzaitine Formations in the western part of Mursuq basin [27]. These stratigraphic units are almost recognized in G. Al Uwaynat province. So, this province has favourable characteristics for uranium potential. Precambrian rocks with younger granite intrusives are present on its south east side. Thus, favourable sources and hosts are present.

Um Kharit Rift Basin Province: This speculative rift system [28] is located to the southeast of Aswan. It is about 150 km in length and 40 km in width (Fig.1). In this basin a great succession of Paleozoic and Mesozoic sediments are present and the continental clastics are often prevailing in the lower parts of the succession. This rift is bounded from the east, west and south by Precambrian basement rocks which include post orogenic granites. These granites show great number of radiometric anomalies, secondary and some primary uranium mineralization [19]. The mode of occurrence of this province and the associated geologic and metalogenic environments increase its potentiality for identification of uranium deposits.

Um Bogma Province: The Paleozoic sediments in Um Bogma area are subdivided into the lower sandstone, the middle dolomite and limestone and the upper sandstone. The middle dolomite unit is composed of brown to grey dolomite, limestone, shale, silt, claystone and sandstone. The shale is varicoloured and contains organic matters of varying concentrations, while sandstone is ferruginated and highly argillaceous, claystone is ferruginated and contains organic materials. Green copper minerals were found in silt as filling fissures and cavities. Siltstone clay and sandstone showed radioactive anomalies incorporated between the two carbonate horizons. The manganese-iron ore horizon is found at the base of this unit. The uranium content in sandstone beds range from 105 ppm to 438 ppm, while in silt beds it ranges from 955 ppm to 5083 ppm [26]. The basement tectonic map [29] shows that Um Bogma area is an ENE trending tectonically controlled basin-like structure. In the writter's opinion, Um Bogma province has a good potentiality for identification of workable uranium deposit. The basement rocks which represent source areas are nearby, hydrothermal activity could have some contribution, high iron content and presence of organic matter in some Paleozoic units often have an important role. Moreover, the Paleogeography of the area, the high density of faults and fractures in addition to the presence of oil fields in the nearby area often have a certain role in deposition and redistribution of uranium in this province.

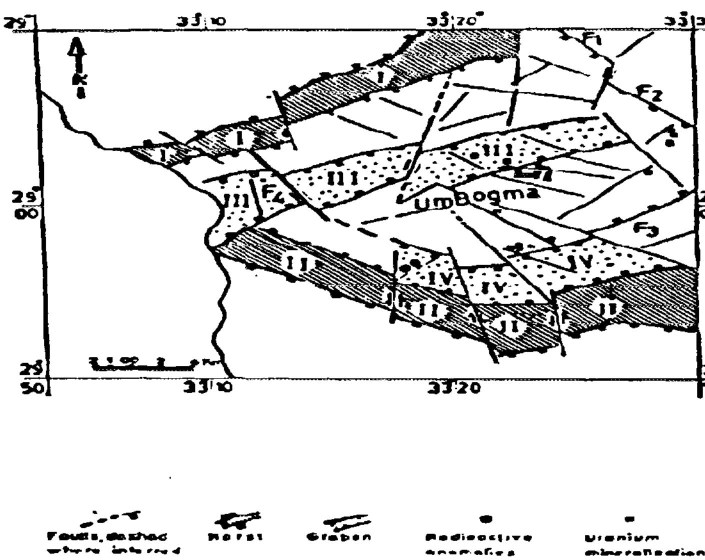


Fig. 2 : Basement tectonic map of UM bogma Brovince, Sinai, Egypt (after El kattan and El Aassy, 1992).

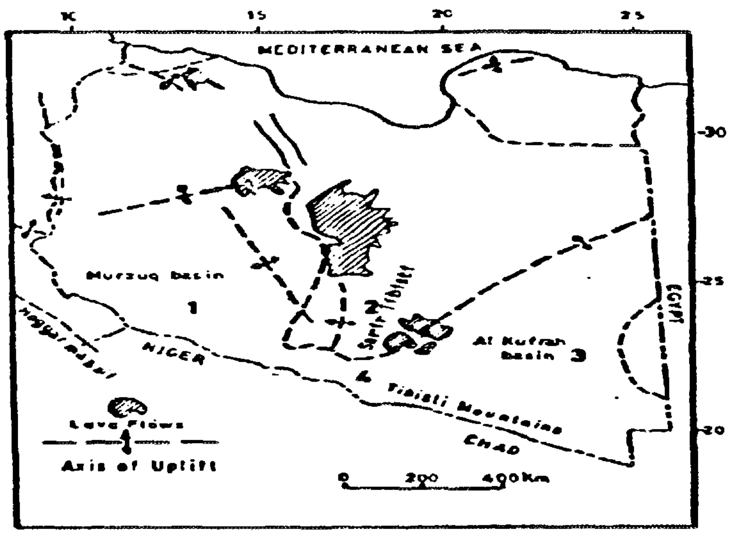


Fig. 3 : Map Showing the potential uranium provinces (1, 2, 3 and 4) in southern Libya (tectonic framework after Goudarzi, 1978).

3-2- Libya

Libya, situated on the Mediterranean foreland of the African shield, extends over a platform of cratonic basins. The Precambrian basements rocks are mainly exposed in Tibisti Mountains in the southern part of the country. The rest of the country is covered with sedimentary sequence ranges in age from Paleozoicto Quaternary. Tertiary volcanic rocks are widely spreaded in Al Haruj Al Aswad and G. Nuqay [30]. The available information about uranium in Libya indicate the presence of uranium occurrence in Ghat area at the south western part of the country. It occurs within continental Permo-Triassic sandstone and siltstone along the flanks of Murzuq basin [31]. The reported uranium minerals include tyuyammunite, carnotite and betauranophane [32].

The regional geologic and tectonic features of Libya have been reviewed in the light of recognition criteria for identification of uranium provinces. Three major basins are considered by the writer as potential uranium provinces. These basins are: Murzuq basin, Sarir Tibisti trough and Al Kufra basin. It is noteworthy to mention that the granitoid rocks in the southern Libya represent a potential uranium province.

3-2-1. Murzuq Basin

It lies in the southwestern part of Libya (Fig.3) and extends about 700 km with curvilinear axial trend following NE in general and has about400 km width. The basement is about 3000 m b.s.l. near the centre of the basin[30].The basin is filled with a thick sequence of clastic sediments formed mainly of sandstone and shales. These sediments are mainly continental and belong to Palaeozoic and Mesozoic ages.

This basin has a good potentiality for the presence of uranium deposits. It has some uranium occurrences at its western flank in Ghat area. The most interesting observation is its presence to the north of Niger and to the east of Hoggar deposits [33]. One of the most interesting uranium dicoveries in the past decade is that in the Mesozoic sandstones near Arlit in the Niger where reserves are estimated by the CEA to be at least 25000 tons U30g [34]. A sandstone type deposits west of the Air massif in Niger, on the eastern side of the Agades, production and reserves from carboniferous, Permian and Cretaceous sandstones, are recognized. Moreover, Lower Paleozoic Ajjer Formation, Tassili series, Algeria, Sandstone type significant deposits are recognized, in addition to the presence of vein and stockwork environment as a significant deposit in Late Proterozoic gneisses in Hoggar massif to the southwest of this basin [35]. The Murzuq basin is nearby surrounded by the same Carboniferous and Permo-Triassic units which have proved productive in nearby Niger, and the Dijado plateau of the Niger portion of the Murzuq basin has been prospected with some success.

3-2-2. Sarir Tibisti Trough

It lies between Tibisti - Al Haruj uplift at the west, G. Nuqay at the east and Tibisti Mountains at the south. The depth to basement in this trough is about 4000 m. Little information is known about the stratigraphy of this trough, however, some surface exposures of the ordovician - Cambrian and Eocene are present. This basin is surrounded by basement rocks which include Pan-African younger granites in the form of U shape. Moreover, a huge volcanic activities are noticed in the eastern and northern parts of this basin (Fig.3). This trough has received water and sediments from nearby source areas which are probably uraniferous. The area appears particularly interesting with respect to uranium potential.

3 - 2- 3. Al Kufrah Basin

It is located in the southeastern part of Libya with axial trace following NNE. It is limited from the east by G. Al-Uwaynat uplift, G. Az Zalamah uplift from the northwest and Tibisti mountains from the southeast [30]. The basin is covered with a thick sequence of sedimentary rocks of the Palaeozoic and Mesozoic ages. The Palaeozoic sediments range in thickness from 1055 to 1850 m, its lower part (1300 m) is continental, mainly fluviatile and localy marine. The upper part (550m) shows ossilation from continental to marine. The Mesozoic sediments ranges in thickness from 200 m to 735 m and they are mainly continental [36]. This basin can be consider as a good target for uranium exploration. This belief is based upon the presence of a thick succession of Palaeozoic and Mesozoic mainly continental clastic sediments. Moreover, some radioactive anomalies are recorded in the basal conglomerate and the Palaeozoic sandstones in Egypt near G. Al-Uwaynat [25].

3-2.4 Granitoids Uranium Province

The Bin Ghanimah batholith and Tibisti massif are formed of Precambrian basement rocks and include some alkali-rich granites of Pan-African age [37]. It is evident that major uranium deposits are associated with igneous activity in at least two PanAfrican belts. The Rossing deposits of Namibia occurs in pegmatite - alaskite migmatite bodies in the Damaran belt, and broad areas of uranium mineralization are associated with emplacement of the younger granites of Egypt [4]. This fact can be utilized as a guide for uranium exploration in Pan-African granitoids and the associated igneous rocks in Tibisti mountains (Fig.3).

3-3. Saudi Arabia

Saudi Arabia is covered with basement and sedimentary rock groups. The basement rocks are mainly concentrated in the western part of the country forming a part of Arabian Shield (Fig.4). They are mainly represented by ophiolitic rocks, volcanic sedimentary sequences, granitic rocks and some Tertiary - Recent basalts [38].

These basement rocks are flanked from the east and northwest by a thick sedimentary sequence ranges in age from Palaeozoic to recent [39]. A scarce information about uranium in Saudi Arabia is published. All known radioactive anomalies are recognized in granitoid rocks [21 and 40]. The reviewing of geologic and tectonic features in the light of uranium favourability in Saudi Arabia indicates the presence of some potential uranium provinces in the Palaeozoic sedimentary rocks and the Pan-African granitoides.

3-3.1. Palaeozoic Province

The most interesting Palaeozoic exposure is located to the NWof Saudi Arabia. The stratigraphy and lithology of this exposure need to be studied to find out the recognition criteria favourable for identification of sandstone uranium type deposits. It is noteworthy to mention that some secondary uranium mineralizations are recognized in Abu Zenama (West Sinai, Egypt) Paleozoic rocks where uranium minerals are associated with sandstone, siltstone, and conglomerate of the Lower Carboniferous age [41]. Moreover, in Wadi Araba area, North Eastern Desert, Egypt, an outcrops of late Palaeozoic highly ferruginated sandstone and siltstone beds are surveyed. Several high radiometric anomalies associated with relatively high uranium content were recorded in these beds [42]. Another indication for the Paleozoic rocks potentiality for uranium is the presence of radioactive anomalies in the Palaeozoic rocks in G. Al Uwaynat area, southwestern Desert, Egypt [25]. Accordingly, the Palaeozoic rocks in the northwestern part of Saudi Arabia can be considered as a good target for uranium exploration.

3-3.2. Granitoid Rocks

The granitoid rocks are frequently exposed in the north eastern, southwestern and northwestern parts of the Arabian Shield (Fig.4). By reviewing the uranium favourablity of the granitoid rocks, it is found that the younger granites are the most favourable. A wide survey has been performed on 17 granite plutons in the northwestern Arabian Shield [21]. It is found that these granites are anomalously uraniferous especially the peralkaline and peraluminous post-orogenic granites which intruded between 570 to 620 Ma ago. They have low initial Sr ratios from 0.7029 to 0.7051. These granites are chemically similar to those have been identified as favourable for the occurrence of magmatic uranium deposits [21]. The same authors [21] found that low Th/U ratios and high U/K ratios argue against any concentrating of uranium by magmatic processes. These ratios suggest also that little if any uranium has been lost at any point in the history of these granites.

Moreover, the near equilibrium value of U/Ra eU ratio indicates that leaching of uranium from peraluminous granites has not occured within the last thousands years. However, the study of Hql granite in Midyan region, NWof Saudi Arabia indicated the presence of high U and Th contents. Uranophane was identified at one of the anomalous localities [40]. The same authors noticed a wide range of eU/U, Th/U and U/K ratios and they considered the hydrothermal action was responsible for the redistribution and enrichment of U and Th.

In the writer's opinion the granitoid rocks in the Arabian Shield at Saudi Arabia could be considered as potential source for uranium. It is importantto concentrate the exploration efforts on the peraluminous, double mica, Mo, F, Sn rich late to post orogenic granites. Moreover, the marginal parts of these granites represent good target where the Egyptian exploration experience proved that most of the localized uranium mineralizations are restricted to the marginal zones of the younger granite plutons [22]. So, in these younger granites, small to moderate scale uranium deposit can be predicted.

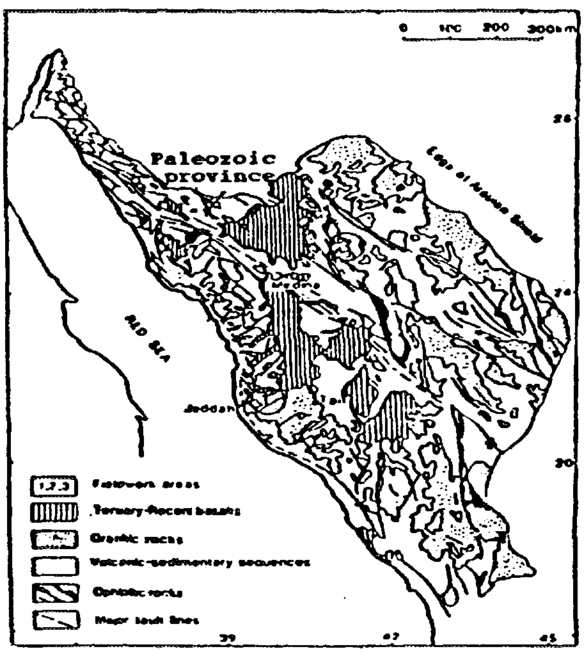


Fig. 4 : Map showing major rock types and structure of the Arabian shield[38], showing the potential paleozoic and granitoids provinces.

3-4. Sudan

The exposed rocks in Sudan are represented by Precambrian basement complex, Mesozoic and Tertiary sedimentary rocks. The basement complex is composed of granodioritic quartzo-feldspathic gneisses, migmatites, amphibolite-grade metasediments, gabroic bodies and syntectonic granites. These rocks have been intruded by a suite of anorogenic alkali granites and syenites that represent the last major magmatic event in the area. The surrounding unmetamorphosed sedimentary units include the Mesozoic Nawa Formation, composed of mudstone and minor limestone, the Cretaceous Nubian Sandstone Formation and Tertiary-Quaternary unconsolidated sediments [43] .

A limited infomration about uranium in Sudan is available. one radiometric anomaly has been located in Uro, Nuba Mountains, following a zone of tectonic breccia. Maximum levels of A_2O_3-35.4%, P_2O_5-26.1%, U-2220ppm, F-7900ppm, Ba-14000 ppm, V-3080 ppm and sporadic highs in Cr, Cu and Zn occur in aluminous phosphate (crandalite). The tectonic breccia is confined to a long, steeply westward dipping fracture zone which cuts the graphitic slates. The width of the zone varies from 7 to 40 m and it is 1.5 km long. The rocks occupying the zone are made up of angular fragments of slate, quartzite, and marble [43].

Another radioactive anomalies have reported in Miri locality, Kadugli area in the southern part of Kordofan Province in the Nuba Mountains. The mineralized veins are hosted in granitic rocks, Th dominated but do contain anomalous amount of uranium. The U content ranges from 13 to 300 ppm, while Th content ranges from 5 to 769 ppm. The mineralized veins are rich in Zr=11381, Nb=4017, Y=1160, Ce=5168 and La=1092 ppm [44].

On the light of the available information about uranium and the regional geologic and tectonic aspects some geologic environments can be considered as targets for potential uranium provinces in Sudan. These are intracratonic rift basins and granitoid rocks.

3- 4.1. Intracratonic Rift Basins

These rift system were developed during Cretaceous tension tectonics in the southern Sudan. In these basins a thick sequences of non-marine rocks were accumulated. These rocks are represented by arkosic sandstones which deposited in a fluvio-lacustrine environment.

Moreover, the associated shales and claystones deposited in anoxic environment and contain from 5 to 20% organic matters. These rifts are represented by Muglad (Abu Gabra), Meult and Blue Nile basins (Fig.5). Abu Gabra basin joins with central and west African rift system through the south of Chad rift in the central part of the continent. Most of the discovered oil field in the southern Sudan are concentrated in Abu Gabra basin [28].

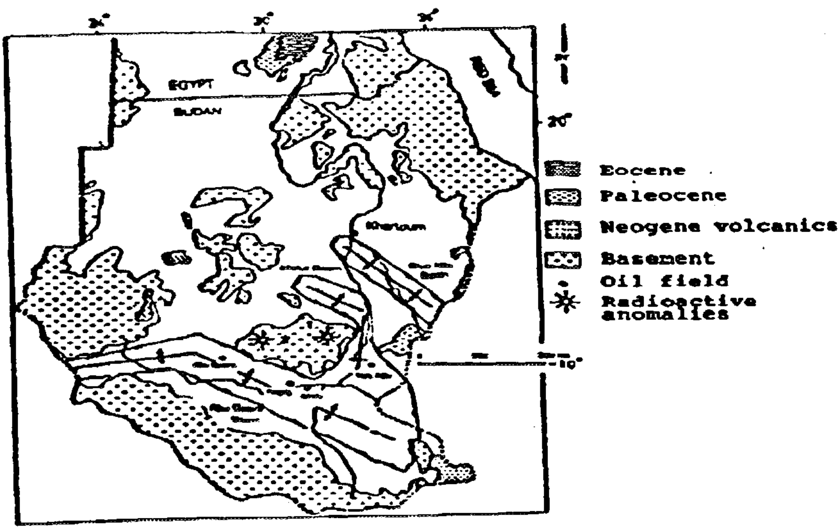


Fig. 5 : Rift basins in sudan (28), showing location of some radioactive anomalies and potential Abu Gabra rift basin.

These rifts especially Abu Gabra can be considered as a potential uranium province where it has most of the recognition criteria for identification of sandstone type uranium deposits. In addition to the presence of thick continental sandstone associated with organic matter rich-shale beds, the presence of oil can act as reductant factor. Also, these basins are surrounded with huge terrane of basement rocks that include some U-rich varieties which act as a good source for uranium.

3- 4.2. Granitoid Rocks

The granitoid rocks in Sudan are represented by batholithic granites and younger granites. The batholithic granites are of calc-alkaline type.

The younger granites are post tectonic, epizonal alkali, MgO-poor and highly silica-saturated [37]. The granitoides especially the younger granites can be considered as potential uranium provinces. It is note worthy to mention that some granitic and syenitic rocks in Nuba Mountains shows high content of uranium and thorium [43 and 44]. So, the post orogenic granites of Sudan could be considered as target provinces with good potentiality for vein and disseminated type uranium deposits.

4- Conclusion

The following potential uranium provinces in the studied Arabian countries can be considered as targets for uranium exploration.

In Egypt, post orogenic granites are of high potentiality to identify vein type uranium deposits especially at the marginal zones of the plutons. G. Qattar, El Missikat, El Erediya and Un Ara provinces are the best examples.

Two intermontane basins include Hammamat molase - type clastic sediments, one of them is located to the south of wadi El Kareim area where numerous uraniferous bostonites and post orogenic granites are present. The other one is represented by G. Um Tawat area where uranium mineralization and strong hydrothermal activities are found in its southern contact with G. Qattar post orogenic uraniferous granite. This environment is rather suitable for the formation of uranium deposit. The Paleozoic basins with continental clastic sediments in Gebel Al Uwaynat (SW Egypt), UM Kharit (south Eastern Desert) and Um Bogma (West Sinai) are located nearby the uranium source areas. These basins are potential for sandstone and surfacial uranium deposits.

In Libya, Murzuq and Al Kufra basins/ and Sarir Tibisti trough include a thick clastic continental sequence of Paleozoic and Mesozoic sediments which can host workable uranium deposits. The Tibisti massif represents a source area and potential host for uranium, as evidenced by the productive deposits in both Algeria and Niger. Various types of uranium deposits are possible in the southern Libya provinces.

In Saudi Arabia, the Paleozoic clastic continental sediments especially those located to northwestern part of Arabian Shield can be considered as a good target for uranium exploration. Moreover, the post orogenic granites which are widely spreaded in the country represent sources for uranium and can also host small to medium scale uranium deposits.

In Sudan, the intracratonic rift basins can be considered as excellent environment for hosting sandstone and surfacial types of Uranium deposits. The re-interpretation of the gamma-ray logs for the oil wells in these rifts could contribute valuable information about uranium exploration. The granitoid rocks surrounding these basins can act as source and also/host for uranium especially in the Nuba Mountains.

The above recommended potential uranium provinces in Egypt, Libya, Saudi Arabia and Sudan are rather suitable for starting regional and detailed exploration for uranium. The characteristics of these provinces and their potentiality for hosting workable uranium deposits could be developed gradually according to the available data in future. Moreover, these ideas can be applied for other Arabian conutries which have similar geologic environments.

Acknowledgements

Many thanks for Prof. Dr. N.T. El Hazek, President of Nuclear Materials Authority (NMA), Cairo, Egypt for his encouragement and valuable discussions. Deep thanks for Dr. M.A. Hassan, Dr. A.A. Ammar, Dr. K.M. Foad, Dr. H.S. Assaf, Dr. I.E. El Aassy and Dr. M.H. Shalaby, (NMA) for providing of some valiable references.

References

[1] Jones, C.A., 1978: A classification of uranium deposits in sedimentary host rocks: In NURE Uranium Geology Symposium (Grand Junction Colo.: Bendix Engineering Corporation), 8-23.

[2] De Voto, R. H., 1982: Uranium exploration: In Uranium geochemistry, mineralogy, geology, exploration and resource, UB/TIB Hannover, FH 2079,101-108.

[3] Tassinari, C.C.G. and P.M.C. Barreto, 1992: Uranium in granitoids: recognition criteria of uranium provinces in Brazil: IAEA-TECDOC-650, 1321 .

[4] Rogers, J.W., 1978: Uranium in Pan-African Belts: Proceedings of the Second Symposium on the Geology of Libya, Tripoli, V. III, 1045-1049.

[5] Dahlkamp, F.J., 1987: Classification scheme for uranium ore deposits. A state of the art review: Proceedings of Technical Committee Meeting on Metallogenesis of Uranium Deposits organized by The IAEA, Vienna, 31 p.

[6] El Gaby, S., K.F. List and R. Therani, 1990: The basement complex of the Eastern Desert and Sinai, Egypt: in "The Geology of Egypt", R. Said, editor, Ch. 10, A.A. Balkema, Rotterdam, Netherland, 175-184.

[7] Bakhit, F.S. and L.A. Guirguis, 1983: Contribution to the granite plutons of both El Missikat and El Erediya, Central Eastern Desert, Egypt: Communication, Dergi Yayin Skreterligi, Ankara Univ., Fen Fakultesi, Besevler- Ankara, Turkey, Ser. C 1, 26, 1-7.

[8] Salman, A.B., Y.A. Sheshtawi, M.M. Aly and E.A. Hamoudah, 1989: Radioelements distribution in some granitoid rocks from the North Eastern Desert of Egypt: Mans. Sci. Bull. 16(1), 17-39.

[9] Abdel Monem, A., F. Bakhit and M.M. Ali, 1990: Trace and rare earth elements geochemistry of the uranium mineralization at El-Erediya, central Eastern Desert, Egypt: Egyptian Mineralogist, 2, 143-150.

[10] Salman, A.B., I.E. El Aassy and M.H. Shalaby, 1990: New occurrence of uranium mineralization in Gabal Qattar, Northern Eastern Desert, Egypt:
Annals of the Geol. Surv. Egypt, V. XVI (1986-1989), 31-34.

[11] Sayyah, T.A. and M.Y. Attawiya, 1989: Contribution to the mineralogy of uranium occurrence of G. Qattar, Eastern Desert, Egypt: Arab J. Nucl. Sci. App., Cairo, Egypt, 23-1, 171-184.

[12] Abou Deif, A., 1985: Uranium mineralization along Qena-Safaga Road: M.Sc. Thesis, Al Azhar Univ., Cairo, 109p.

[13] Hussein, H.A.M. and T.A. Sayyah, 1992: Uranium potential of the younger granites of Egypt: IAEA-TECDOC-650, 58-64.

[14] Greenberg, G.K., 1981: Characteristics and origin of Egyptian younger granites, Geol. Soc. Am. Bull., Part II, 92, 749-840.

[15] Stern, R.J., 1981: Petrogenesis and tectonic setting of late Precambrian ensimatic volcanic rocks, Central Eastern Desert, Egypt: Precambrian Res., 16, 168-172.

[16] Stern, R.J., D. Gottfried, C.E. Hedge, 1984: Late Precambrian rifting and crustal evolution in the North Eastern Desert of Egypt: Geology, 12, 168-172.

[17] Bakhit, F.S. and I.A. El Kassas, 1989: Distribution and orientation of radioactive veins in El Erediya - El Missikat area, central Eastern Desert, Egypt, Int. J. Remote Sensing, 10, 565-581.

[18] Attawiya, M.Y., 1983: Mineralogical study of El Erediya-I uranium occurrence, Eastern Desert, Egypt: Arab J. of Nuclear Sciences and Applications, 16-2, 221 -235.

[19] Abdel Meguid, A.A., 1986: Geologic and radiometric studies of uraniferous granite in Um Ara - Um Shilman Area, South Eastern Desert, Egypt: Ph.D. Thesis, Fac. Sci., Suez Canal Univ., Egypt, 241p.

[20] Hussein, A.H., M.A. Hassan, M.A. El Taher and A. Abou Deif, 1986: Uranium bearing silicious veins in younger granites, Eastern Desert, Egypt: IAEA, TECDOC 361, 143-157.

[21] Stuckless, J.S., I.T. Nkomo, D.B. Wenner and G. Vantrump, 1983: Geochemistry and uranium favourablity of the postorogenic granites of the Northwestern Arabian Shield, Kingdom of Saudi Arabia: Bull. Fac. Earth Sci, King Abdulaziz Univ., 6, 195-209.

[22] Salman, A.B., M.H. Shalaby and L.M. Nossair, 1990: Uranium province, North Red Sea Hills, Egypt: Proceedings of the International Earth Sciences Congress on Aegean Regions, Izmir, Turkey, 1 -6 october 1990, V.1, 89-101.

[23] Salman, A.B., 1983: Uranium potentiality and significance of the bostonite generations, central Eastern Desert, Egypt: Ain Shams Sci. Bull. No. 24-B, 1982-1983, 63-81.

[24] Klitzsch, E., 1990: Paleozoic: in The Geology of Egypt, R. Said, editor, ch. 21 A.A. Balkema, Rotterdam, Netherland, 393-406.

[25] El Aassy, I.E.E., 1984: Contribution to the radioactivity of Paleozoic rocks in Gebel Oweinat Area, Southwestern Desert, Egypt: Arab. J. of Nuclear Sciences and Applications, Cairo, Egypt, 17-2, 339-355.

[26] El Aassy, I.E.E., 1990: Uranium potentiality of some Paleozoic sections in Egypt: Annals of the Geol. Egypt, V. XVI (1986-1989), 83-87.

[27] Almehdi, B., S. Gojkovic, M. Megrisi, M. obrenovic, D. Puric and J. Zelenka, 1991: Radioactive elements in sedimentary rocks of the western part of Murzuq Basin, Libya: in the Geology of Libya, 3rd Symposium on the Geology of Libya, held in Tripoli, September, 27-30, 1987, V. VII, 2645-2658.

[28] Nagati, M., 1986: Possible Mesozoic rifts in Upper Egypt: An anology with the geology of Yemen-Somalia rift basins: EGPC 8th Exploration Conference, Cairo, Egypt, 20p.

[29] El Kattan, E.M. and I.E. El Aassy, 1992: Structurally controlled radioactivity in the Um Bogma Area, Midwestern Sinai, Egypt: The Arabian J. of Sci. and Engineering, 17-1, 45-59.

[30] Goudarzi, G. H., 1978: Structure - Libya: Proceedings of the Second Symposium on the Geology of Libya, Tripoli, September 16-21, 1978, V. Ill, 879-892.
[31] Assaf, H.S. and M.G. Aburkes, 1980: Uranium occurrence in Ghat area, Southwest Libya: Annals of Geo. Surv. Egypt, V. X, 871-879.
[32] Baegi, M.B., H.S. Assaf and K.M. Hangari, 1991: Al Awaynat surface uranium mineralization - A new approach to its origin: in the Geology of Libya, 3rd Symposium on the Geology of Libya, held at Tripoli, September 27-30, 1987, V. VII, 2619-2626.
[33] Wilpolt, R.H. and S.D. Simov, 1979: Uranium deposits in Africa, IAEA-AG 10911, 5-19.
[34] Bowie, S. H. U., 1970: World uranium deposits: Proceedings of Uranium Exploration Geology Panel, Vienna, 13-17 April, 1970 (IAEA-PL-391 /19), P. 23-34.
[35] Goodell, P.C., 1991: Uranium potential in and around the Tibisti and Hoggar Massifs: In the Geology of Libya, 3rd Symposium on the Geology of Libya, held in Tripoli, September, 27-30, 1987, V. VII, 2627-2636.
[36] Bellini, E. and D. Massa, 1978: A stratigraphic contribution to the Paleozoic of the southern basins of Libya: Proceedings of the Second Symposium on the Geology of Libya, Tripoli,V. I, 3-56.
[37] Ghuma, M.A. and J.W. Rogers, 1978: Pan African evolution in Jamahiria and North Africa: Proceedings of the Second Symposium on the Geology of Libya, Tripoli, V. III, 1059-1064.
[38] Duyverman, H.J., 1984: Late Precambrian granitic and volcanic rocks and their relation to the cratonisation of the Arabian Shield: Proceedings of a Symposium on Pan-African Crustal Evolution in theArabian-Nubian Shield, I.G.C.P. No. 164, held on 1-3 Feb. 1982, K.A. Univ., F.E.S. Bull., No. 6, 49-69.
[39] Powers, R.W., L. F. Ramirez, C. D. Redmond and Jr. E. L. Elberg, 1966: Geology of the Arabian Peninsula, sedimentary geology of Saudi Arabia, U.S. Geol. Survey Prof. Paper, 560-D, 147p.
[40] Alfotawi, B.A., M.A. Gazzaz and M.A. Hassan, 1991: Uranium and thorium environment in Haql granite in Midyan Region, Northwest of Saudi Arabia: J. KAU, Earth Sci, 4, 161-170.
[41] Afifi, Sofia, Y., 1991: Geochemical investigation of some radioactive lower Carboniferous sedimentary rocks of Wadi Nasib area, West Central Sinai, Egypt: M.Sc. Thesis, Fac. Sci., Suez Canal Univ., Egypt, 250p.

[42] Salman, A.B. and I.E. El Aassy, 1983: Radioactivity and uranium distribution in Wadi Araba Late Paleozoic sediments, north Eastern Desert, Egypt: Annals of Geol. Surv. Egypt, 13, 53-60.
[43] Sadig, A., Y.M. Ahmed, B.W. Charbonneau and G.M. Lecheminant, 1988: The Uro radiometric anomaly - uraniferous phosphate in a tectonic breccia (Nuba Mountains), Kordofan Province, Sudan: Uranium, 4, 351-363.
[44] Parslow, G.R., B. Khalil and A.R.K. Hassan, 1992: Baseline uranium exploration surveys and their use in the early detection of potential natural hazards: A case history from Sudan: Proceedings of a Technical Committee Meeting, Vienna, (IAEA- TECDOC-650), p. 22-29.