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Metallogenic evolution of uranium deposits in the Middle East and North Africa deposits

Fares Howari [a,*], Philip Goodell [b], Abdulaty Salman [c]

[a] College of Sustainability and Human Sciences, Zayed University, Abu Dhabi, United Arab Emirates
[b] Department of Geology, University of Texas at El Paso, 500 W University Ave, El Paso, TX 79968, USA
[c] Nuclear Material Authority, P.O. Box 530 El-Maadi 11431, Cairo, Egypt

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ABSTRACT

This paper is briefly involved in classification and distributions of the Middle East and North Africa (MENA) uranium deposits. The study of these mineral systems can significantly contribute to our further understanding of the metallogeny of known and poorly explored deposits. This provides contribution to, and further enhancement of, current classifications and metallogenic models of uranium systems, allowing researchers to emphasize on unknown or poorly studied mineral systems found in MENA. The present study identified eight metallogenic types of uranium associated with: 1) the Archean rocks and intracratonic basins, 2) the Pan-African granites and rhyolites which are characterized by igneous activity, 3) Phanerozoic (Paleozoic) clastics, these deposits are the sedimentological response to Pan African magmatism, 4) Mesozoic (basal) clastics type e.g. Nubia sandstones which are characterized by uranium minerals, 5) regional sedimentary phosphate deposits which are categorized as geosynclinal, or continental margin deposits, on the shelf of the Tethys Ocean, 6) Cenozoic Intracratonic Felsic Magmatism of the Tibesti and Hoggar, and the sandstone U deposits of adjoining Niger. These are similar to the Pan-African magmatism metallogenic, 7) Calcretes, and 8) Resistate minerals which are often enriched in rare earth elements, sometimes including uranium. They are thus sometimes considered as U resources but poorly explored in the MENA region. These metallogenic types are described and discussed in the current paper.

Contents

* Corresponding author.
E-mail addresses: fares.howari@zu.ac.ae, fmhowari@gmail.com (F. Howari).

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1. Introduction

Metallogenic research focuses on the genetic association among the geological history of an area, its structural setting and its mineral deposits, and is focusing on providing an adequate understanding of the geological settings and nature of economic metal deposits in the province, and to employ this understanding to assist and orient exploration programs to regions of strong mineral exploration potential. Toward this end, metallogeny involves in the documentation of broad geological characteristics of mineral deposits, the association of deposits by geological type and tectonic setting, and the better understanding of the origin and genesis of the deposits as provided by independent knowledge of the tectonic setting. The regional tectonic setting is scaled upward to be a part of the known plate tectonic history of the region. Metallogeny is useful in mineral exploration and in estimation of the potential mineral resources of a region (Mahadevan, 1988; Zheng et al., 2015; Abzalov et al., 2015).

The present study will relate the potential uranium provinces and known deposits in the Middle East and North Africa (MENA) region to the geological environment and tectonic history of the region and vicinity. The present paper will present a metallogenic classification of uranium in the Middle East. The regional geology and tectonics determine the ore deposit types expected. Most types published in literature are then made relevant to the Middle East by giving them the relevant Middle Eastern names. Thus the A-granite/rhyolite magmatic/volcanogenic type of U deposit becomes the Pan-African granite/rhyolite U metallogenic type and province. The U metallogenic types adapted for the Middle East are given in subsequent sections.

1.1. Uranium provinces recognition criteria

Uranium resources provinces and metallogenic types recognition criteria depend upon the characteristics of the host and the surrounding geologic environments (Salman, 1995). It is important to concentrate upon the recognition criteria for uranium in granites and sandstones rocks. These criteria will be utilized for predicting potential uranium in the MENA region.

Granites and sandstones rocks are the most important for hosting the main uranium resources. The recognition criteria for identification of uranium resources in granites mainly include uranium contents, formation ages, lithology and associated tectonics. The average uranium contents in various types of granites should be accurately determined. This is rather important to differentiate between the uranium-enriched granites and normal granites. For example, in Brazil the average uranium content in normal samples is about 3–7 ppm. They considered the 12 ppm uranium as a limit between uranium-enriched and normal granites (Tassinari and Barreto, 1992). It is found that uranium contents are 5–10 ppm and thorium contents are of 15–25 ppm in samples from one enriched granite pluton of Pan-African Shield, thus yielding Th/U ratios of 2–2.5 (Rogers, 1978). The low Th/U ratios of granites are interesting in view of the fact that most highly differentiated granites have Th/U ratio 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 frequencies for uranium enriched granites are noticed at the time interval of 2600–2000 Ma, 2200–1800 Ma and 900–500 Ma (Tassinari and Barreto, 1992).

It is evident that the uranium contents distribution are related to different granitic lithological groups. The granites with granitic compositions and the alkaline granites present higher uranium concentrations. In general the U-enriched alkaline granites 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 (Dahlkamp, 1987). 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 vary according to the type of the deposit (Dahlkamp, 1987). Uranium as disseminations in dominantly continental fluvial arkosic sandstone, commonly interbedded with argillaceous horizons, and almost flat morphology (5°) unless post-ore tilted; frequently associated with tuffaceous sediments. A difference is made between: (a) Phanerozoic (Post Devonian) formations related to terrestrial plant derived organics and (b) Proterozoic formations related to algae derived volcanics (Rogers, 1978). In the roll front, two classes are present, continental basin and coastal plain. In the continental basin U present as disseminations at redox boundary in arkosic and subarkosic sandstones precipitated in intracratonic or intermountain basins, in the vicinity of rocks having anomalous U concentrations of fluvial origin such as tuffs or granites essential. Most formations occur within bedded sequences sandstones rich sediments of volcanic origin without major time or erosional breaks.

1.2. Uranium geochemistry and deposit classification

With respect to the present discussion of the metallogeny of uranium in the MENA, several points must be emphasized, first of all, the geochemistry of uranium, its behavior in earth processes, is very versatile. Uranium exists at different valence states: U^{3+} U^{4+} U^{6+}. Under reduced conditions, uranium U^{4+} hydroxide or fluoride complexes are the only dissolved species (Gascoyne, 1992). Hexavalent uranium is relatively soluble with the solubility in aqueous systems controlled by three factors: oxidation–reduction potential, pH, and dissolved carbonate (Murphy and Shock, 1999). Uranium can be enriched in many different geologic environments. There are many ways of U ore deposit formation, which are produced by geochemical features of rocks and the element uranium. The basic way of U ore genesis is host mineralogy, oxidation/reduction potential (E_h), and porosity. Uranium dissolves fast, and it is a radioactive heavy metal. It can be transported and precipitated in groundwaters due to changes in the Eh conditions (Forstner, 1982; Forstner and Wittmann, 1983; Dahlkamp, 1987; Abdel Monem et al., 1990).

Uranium is not compatible with magmas, and hence it accumulates in severely fractionated and evolved granite melts and phases, particularly alkaline examples. These phases tend to become highly saturated in U, Th and K, and could create internal pegmatites or hydrothermal systems into which uranium may dissolve. This property is reflected in the diverse classification of uranium deposit types, as discussed in the International Atomic Energy Agency (IAEA) classification. This classification describes fifteen main categories of U deposit types: 1) Unconformity-related deposits, 2) Sandstone deposits, 3) Quartz-pebble conglomerate deposits, 4) Breccia complex deposits, 5) Vein deposits, 6) Intrusive deposits (Alaskites), 7) Phosphorite deposits, 8) Collapse breccia